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TEMPERATURE COMPUTER MEASUREMENTS, PRODUCTION AND CARCASS TRAITS OF INDIVIDUALLY FED WEIGHT CONSTANT STEERS

BY

LOWELL M. ANDERSON

A thesis submitted
in partial fulfillment of the requirements for the
degree Doctor of Philosophy, Major in
Animal Science, South Dakota
State University

1971

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TEMPERATURE COMPUTER MEASUREMENTS, PRODUCTION AND

CARCASS TRAITS OF INDIVIDUALLY FED

WEIGHT CONSTANT STEERS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Doctor of Philosophy, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

Head, Animal Science Department Date

TEMPERATURE COMPUTER MEASUREMENTS, PRODUCTION AND CARCASS TRAITS OF INDIVIDUALLY FED WEIGHT CONSTANT STEERS

Abstract

LOWELL M. ANDERSON

Under the supervision of Professor C. A. Dinkel

During 1968, 29 Hereford steers were individually fed and marketed at one of seven constant weight classes from approximately 386 to 522 kg at intervals of 22.7 kg. During 1970, 21 Angus and Hereford crossbred steers were individually fed and marketed at one of four constant weight classes from approximately 386 to 522 kg at intervals of approximately 45.0 kg. The amounts of edible portion, trimmed fat, removed bone and the summation of the kidney, pelvic and cod fat were determined on the steers of both years. In 1970 two experiments examined the usefulness of an analog computer for calculation of heat loss of individually fed steers raised in a near normal or conventional environment. The instrument was equipped with eight skin leads, a rectal and an ambient probe. The computer used combinations of sensed temperatures and manually set factors to calculate heat production. Experiment one utilized six Angus and Hereford crossbred steers to evaluate sources of variation associated with the temperature computer measurements. Experiment two included measurements taken during the five day period prior to slaughter before and after feeding on each of the 21 steers assigned to weight classes. Combinations of production and calculated heat losses were used to partition the theoretical energy utilization during the intervals between weight classes.

The edible portion growth of the steers of both years was characterized by a plateau or reduction near the middle of the weight range and an increased amount of edible portion after the plateau. Lower feed consumption and slower gains appeared to be associated with the plateau or reduction of edible portion. The results of the 1970 trial suggested a reduction of feed consumption and production of less edible portion and more fat and bone during the middle interval as compared to the other intervals.

Ambient temperature significantly affected the temperature computer measurements in both experiments. After adjustment for ambient temperature effects, no differences were observed for measurement period within the same day. No important differences were observed for weight classes or breed of sire.

Calculated metabolizable energy intake and temperature computer measurements of heat loss were utilized to compare the theoretical partition of energy utilization between weight class intervals of the 1970 trial. The average metabolizable energy intake was considerably lower for the middle interval. The apparent available energy above that accounted for by the temperature computer heat loss was also considerably lower for the middle interval than for either the first or third interval. The apparent reduction of energy intake during the same interval as the reduction in edible portion occurred was suggested as a possible cause of the plateau. Alterations in protein metabolism and deposition similar to those which occur during semi-starvation studies were theorized as possible explanations for the occurrence of the edible portion plateau. Data from all steers suggested that considerable variations and reductions in feed consumption and performance occurred during the interval between weight classes 3 and 5.

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INTRODUCTION

Consumer demand and economic pressures challenge the beef industry to produce a high quality edible product which contains a high lean to fat ratio and is economical for the consumer as well as profitable for all segments of the industry. The animal scientist is challenged with the investigation and examination of factors which may improve future industry production. The identification of genetically superior animals and the efficient management systems for the economical production of this high quality, high lean to fat ratio product are important steps toward meeting the industry challenge.

The practice of marketing cattle at younger ages suggests that the relative effects of weight would be more important than those of age on efficient production of beef. The total amount of edible portion expressed as the summation of all trimmed retail cuts plus all trimable lean is an important endpoint in the current industry market. Previous research at this station reported by Dinkel et al. (1969) has suggested some interesting trends in the growth of edible portion. These trends include the tendency for the slope of the edible portion growth curve to plateau near the middle and increase near the end. However, studies of metabolic function or examination of the beef steer as an input-output device are necessary for seeking explanations for these occurrences and providing recommendations for the industry.

Assuming that the beef steer can be considered as an input-output device with which we wish to measure changes in the production of edible portion, we must define the components and methods of measurement. Basically all energy consumed is used for maintenance of normal body function, production of body tissue or lost as heat. Assuming that the metabolizable energy values which have been determined in the respiration chambers can be applied to the common feedstuffs, metabolizable energy intake can be calculated by measuring only feed consumption. The measurement of carcass output at different points in the growth curve should provide an estimation of body tissue gain. Therefore, the only major component which needs a method of measurement is the heat loss.

A possible device for determining or estimating heat loss is the Brookline Temperature Computer. This instrument has been used to measure the heat loss of humans in hospitals in fairly conventional environmental conditions. Therefore, the adaptation of the temperature computer appeared to be a feasible method of estimating the heat loss of steers raised in a near normal or conventional manner.

The overall objective of the present study was to examine the usefulness and the relationships between temperature computer measurements, production traits, carcass traits and edible portion growth of individually fed weight constant steers raised in a near normal or conventional manner.

The specific objectives were to:

1. Examine the effects of ambient temperature upon temperature computer measurements with respect to:

A. The effects of repeated measurements to determine period within the same day, measurement time during growth and sire group differences.

B. The relative effects of weight class and the relationship of heat loss to the edible portion growth curve.

2. Examine sources of variation of the 1968 and 1970 individually fed weight constant steers in production, carcass composition and quality traits.

3. Examine the theoretical energy utilization in terms of the following components for comparing the energy utilization for production of carcass composition between weight classes:

A. Metabolizable energy = average feed consumed x 2583.6 kcal per kg intake

B. Temperature computer heat loss per hour x 24

C. Basal metabolism (70 x body weight in kilograms raised to the 3/4 power)

D. Energy in gain

E. Energy for activity and/or unaccounted for (by difference).

REVIEW OF LITERATURE

The results and discussion of an intensive series of investigations related to the energetics of growth and efficiencies of agricultural processes were reported by Brody (1945). The investigations included in this book and later investigations by the Missouri Agricultural Experiment Station have provided the foundation for many of the investigations related to the evaluation of the efficiencies of animal production.

In more recent years Kleiber (1961) and Blaxter (1962) have reported their research and the results of other workers in the general area of energy metabolism and utilization. Most of the reported research dealing with energy metabolism and factors affecting it have been conducted in respiration chambers and as such have been limited in numbers and usually have not examined the growth of edible product. This study was initiated to examine energy intake and utilization with respect to changes in the edible portion of the carcass.

Environmental Effects Upon Heat Production or Energy Metabolism

A general review of environmental effects upon growth have been summarized by Winchester (1964). Some of the findings were:

1. Ambient temperature influences food intake in a linear manner such that a rise in ambient temperature decreases food intake.
2. In cattle water intake is directly related to ambient temperature and dry matter consumption.

3. Energy conversion relationships change with ambient temperature, resulting in maximal conversion of food energy to net energy at an optimal temperature that varies with species and age.

4. Weight gains are not always greatest at optimal ambient temperature due to differences in body composition of animals reared at one given ambient temperature and those reared at another.

5. High relative humidity imposes stress at high environmental temperatures and is additive to that imposed by temperature.

Numerous researchers have examined the heat production of cattle since the early work reported by Armsby (1903). Among those workers were Forbes _et al_. (1926) who examined the effects of various environmental temperatures upon the heat production of the shorn and fully coated, fasting steer. The authors indicated that the critical temperature of the shorn steer was above 18.2 C. However, the fully coated steer possessed a critical temperature below 15.4 C.

Stewart and Shanklin (1958) examined the effects of growth and environmental temperature upon surface temperatures of Shorthorn, Brahman and Santa Gertrudis heifers raised for 13 1/2 months at constant air temperatures of approximately 10 and 27 C. During this time hair and skin temperatures of the main body, dewlap and navel flap (Brahman only) were taken about once a week. In general, the skin temperature of the animals maintained at 27 C decreased with increasing animal weight and the hair temperature tended to increase with animal weight. However, both the skin and hair temperatures of the animals raised at 10 C tended to decrease with increasing animal weight. After completion of the constant-temperature phase, both the 10 and 27 C groups were subjected to environmental temperatures ranging from about 18 to 43 C for varying periods of time. The hair and skin temperatures measured during this phase indicated that the previous constant-temperature phase had little or no effect on subsequent measurements at other air temperatures.

Rogerson (1960) conducted research with two steers in which heat production and energy retention data were measured at different levels of food intake and at different environmental temperatures. The results indicated that the heat production of fasting animals on low planes of nutrition was not influenced by the environmental temperature in the range of 20 to 40 C. However, on higher planes of nutrition an increasing environmental temperature increased the animal's heat production. According to the author, the major factor determining energy retention in different environments was the heat production of the animal.

Blaxter and Wainman (1961) examined the energy metabolism and heat emission of two steers at the maintenance level of nutrition in environments of -5, 5, 15, 25 and 35 C and at a submaintenance level of nutrition in environments of -5 and 19 C. Shivering was observed at temperatures of -5 and 5 C. Heat production was minimal at environmental temperatures of 15 and 25 C in the maintenance series of experiments. The heat production at -5 C was markedly increased and was not affected by the nutritional level. Energy retention varied in an inverse manner to the variation in heat production. The sensible heat loss was the major component of heat loss. The rectal temperature increased at 35 C but otherwise remained within narrow limits. Trunk surface temperature was reduced at low environmental temperatures and there was evidence that cutaneous vasoconstriction occurred between 5 and -5 C.

Blaxter and Wainman (1964) studied the effect of increased air movement on the heat production and emission of steers. A total of four steers were used in 35 experiments each lasting four to five days in which the effects of variation in air velocity from 0.4 to 1.6 m.p.h. at environmental temperatures of 0, 10 and 20 C on heat production were studied using a respiration chamber. Measurements were made on animals with winter coats and on the same animals after shearing. Heat production was increased 17 to 20 kcal per hour when the animals were standing. Cold temperature and increasing wind speed appeared to cause an increase in heat production. The results indicated that tissue insulation was maximal in animals with coats exposed to the cold and wind but was not maximal when the shorn animals were exposed to comparable conditions.

According to Thompson, Worstell and Brody (1952), the surface temperatures of cows exposed to temperatures from approximately 4.5 to 41.0 C increased linearly until environmental temperatures reached about 18.0 C, at which time they continued their linear increase but at a reduced slope until the temperatures of environment, skin and hair merged at 41.0 C. In addition, the nonevaporative cooling rate, the K value in Newton's Law of Cooling, was virtually constant for the hair-to-air cooling but increased with increasing environmental temperature for the skin to hair cooling, indicating that both the peripheral vasomotor control of the skin and the change in hair coating were extremely important factors in rendering cattle tolerant to very low temperatures. The authors concluded that the lack of heat tolerance in cattle was due to a low threshold and narrow range in sweating.

According to Beakley and Findlay (1955), the skin temperature of calves, measured at temperatures from 15 to 40 C and in two different humidity levels, rose with increasing environmental temperature, humidity and time of exposure. No consistent differences were found between skin temperature at the eight different places on the trunk. Variations between measurements of skin temperature were much larger at the low environmental temperatures. When a calf was subjected to a change of environmental temperature, skin temperature acquired its new value in approximately 10 minutes. The authors suggested that skin temperature may be a useful indication of heat tolerance of cattle.

According to Whittow (1962), large variations in the skin temperature of the extremities were recorded between environmental temperatures of -5.0 and 25.0 C. However, at environmental temperatures above 25.0 C, the extremity temperature and the skin temperature of the trunk were similar. The authors suggested that the variations of skin temperature of the extremities were brought about by changes of blood flow to these parts. They also suggested that in a temperate climate variations in the skin temperatures of the extremities of the ox have a thermoregulatory function.

According to Webster (1968), the average critical temperature of heifer calves is about -9 C in still air and increases to 4 C at a wind speed of 12 m.p.h. The author also suggested the possibility of marked differences in cold resistance between different strains of cattle.

Webster, Chlumecky and Young (1969) compared the performance of young beef cattle kept in a controlled environment at approximately 22 C and outside with and without shelter. The gains obtained during the winter were 131.5, 134.6 and 119.7 kg for the controlled, sheltered and exposed groups, respectively. According to the authors, tissue insulation tended to increase throughout the experiment in all groups, but external insulation was on the average 22% higher in the sheltered and exposed groups than in the control animals. The results suggested that, as a consequence of cold adaptation, both the lower and upper limits of the comfort zone of the animals maintained out-of-doors fell about 1.67 C. The major factor determining the cold tolerance of the animals in this experiment was thermoneutral metabolic rate which was a function of appetite.

Webster and Young (1970) examined the breed and strain differences in the cold tolerance of young cattle raised in different environments. Purebred Hereford and Holstein calves, crossbred Charolais or white cattle, black hybrids and Holstein crosses were compared with regard to various criteria which determine cold tolerance. Calves in each group were kept indoors at 18 C (warm exposed) or outdoors during the winter (cold exposed). Hereford and white hybrids were closely similar in thermal insulation and little difference was observed between cold and warm exposed animals in thermal insulation. Although the cold exposed black hybrids were superior in all criteria of cold tolerance measured, they were also the slowest gaining group. Therefore, the authors suggested that selection for cold tolerance and rapid weight gain might not be directly compatible.

A very interesting approach to the evaluation of environmental effects upon animal production has been reported by Webster et al. (1969) and Webster (1970). These scientists have constructed an artificial cow, "Moocow," which has the approximate dimensions of a 250 kg calf. The surface is of roughened plaster of paris coated with dull black paint. A pumping system circulates water at 15 liters per minute from a water bath regulated at 39.0 C through a network of copper pipes running under the surface of the trunk and extremities. Heat loss is assessed by measurement of the power consumption necessary to maintain an internal temperature of 39.0 C.

According to Webster (1970), measurements of heat losses from live cattle and the "Moocow" were in very close agreement in predicting the effects of wind on heat losses from cattle out-of-doors. A "wind chill" index for cattle was drawn up from these results. According to the authors, measurements of solar and infrared radiation exchanges between "Moocow" and the external environment suggested that cattle with access to an open fronted shed would lose about 5% less heat over the winter than exposed stock. Cattle under total cover would lose about 4% more heat over winter than stock outdoors at the same air temperature but sheltered from the wind and exposed to solar radiation.

Carcass Composition Changes With Increasing Animal Weight

The general practice of marketing cattle at younger ages in recent years has increased the relative importance of weight and decreased the relative effects of age. Dinkel *et al.* (1969) reported some interesting trends in the growth curve of trimmed retail cuts. Three experiments, including one time and two weight constant trials and involving a total of 530 steers of two breeds, were used to evaluate the growth of trimmed retail cuts in relation to animal weight. The results of all three experiments indicated that the growth of trimmed retail cuts in relation to animal weight in the weight range of 206 to 329 kg carcass weight was essentially linear with a tendency toward increasing slope at higher weights. Similar trends were true in data supplied by K. E. Gregory from the Fort Robinson Station's heterosis experiment. The data from all studies indicated that for each kg gained the increase in trimmed retail cuts would be the same regardless of the weight at which that kg of gain was added from about 300 to 600 kg live weight. The authors postulated that the lack of agreement with prior expectations was due to expectations based on (1) growth with respect to age rather than weight, (2) previous growth curves expressed as a percent rather than in kg and (3) slaughter occurring at a different point in the growth curve due to modern management practices. Nearly every growth curve examined indicated a plateau in growth of trimmed retail cuts near the middle of the weight range. Although no significant departure from linearity was indicated by statistical test, the plateau effects appeared important. Also, the tendency for the slope to increase following the plateau was unexpected and unexplained. The authors also indicated that studies of metabolic function should be conducted in conjunction with the evaluation of edible portion growth.

Lofgreen (1963) suggested that the marked reduction in efficiency when cattle were taken to heavier weights was due to an increased heat loss and not an increase in fat production. This observation was the result of an experiment in which a total of 34 cattle were used to compare the efficiency and production of carcass fat and protein differences between the successive carcass grades.

According to Zinn, Durham and Hedrick (1970), the deposition of intramuscular fat is not a continuous process but proceeds in a step-wise pattern at 60 to 90-day intervals. This study evaluated the feedlot growth characteristics and carcass grade factors of 100 Hereford steers and 100 Hereford heifers at 30-day intervals over a 270-day feeding period.

According to Moody _et al_. (1970), the percent edible portion of the right side was significantly higher in group 1 (28 days) but variable for the three successive groups marketed at 28-day intervals from 28 to 112 days on feed. The values of percent edible portion were 61.8, 59.2, 57.1 and 58.3%, respectively, for groups 1, 2, 3 and 4. In addition, muscle tissue from cattle fed 28 days was lower in ether extract and was less flavorful than muscle tissue from cattle fed longer periods. Although marbling tended to increase with time on feed, there were no significant differences in marbling or carcass quality grade between 84 and 112 days.

A system to estimate the net energy values of feeds for a large number of conventionally raised animals known as the comparative slaughter technique has been presented by Lofgreen (1965). Basically, this system involves the slaughtering of an initial group of animals to establish the base line and feeding the remaining animals at different nutritional levels for the same period of time. The animals are slaughtered at the end of the feeding period and the change in composition determined using the difference between the final composition and the initial composition of the base line group.

A later report by Lofgreen and Garrett (1968) described a system for the determination of net energy requirements of growing and finishing beef cattle. The system uses an expression NE_m to represent the net energy requirements and the net energy value of the feed when used for maintenance. A second expression, NE_g, is used to describe the net energy value of the feed for production of weight gain. The data from comparative slaughter trials indicated that the NE_m requirements for both steers and heifers were equal to approximately 0.077 megcal per unit of metabolic body size (weight in kg raised to the 3/4 power). The NE_g requirements of steers were equal to $(52.72_g + 6.84_g{}^2)(W_{kg}{}^{0.75})$, where g = average daily gain in kg. The NE_g requirements of the heifers were given as

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$(56.03_g + 12.65_g{}^2)(W_{kg}{}^{0.75})$. The main advantage of this method of determining energy values over those determined in the respiration chambers is that a large number of conventionally raised animals can be involved.

Energy Intake Effects Upon Composition and Production

Burton and Reid (1969) examined the interrelationships among energy input, body size, age and proximate chemical body composition and energy values of 26 Shropshire wethers. Body weight at a given age was manipulated by feeding different energy levels. The energy levels averaged 278 and 421 kcal of gross energy per kg empty body weight$^{0.73}$ per day. The results indicated that energy input, within the range studied, did not influence body composition in a manner independent of its effect on body mass. In animals containing less than 31% fat, the amount of body components increased linearly with increasing body weight. In animals containing more than 31% fat, the weights of water and protein increased at decreasing rates and the amounts of fat and energy increased at increasing rates as body weights increased. The authors indicated that the overall best fit of the relationship between the body components and body weight was provided by the model, $Y = aX^b$. The use of age in addition to body weight for prediction of body composition added very little.

VanStavern et al. (1970) examined the use of performance data obtained from 10 feeding trials involving 230 individually fed beef steers to evaluate energy intake as a predictor of feedlot performance and certain carcass traits. Multiple regression analyses were used to determine the amount of variation in measures of performance and certain carcass traits which could be accounted for by voluntary energy intake and other covariates. Coefficients of determination for many of the carcass traits such as fat thickness; percent kidney, pelvic and heart fat; ribeye area; dressing percent; cutability grade; marbling score and carcass grade were generally low ranging from 5% to about 25% when digestible energy intake for the entire feeding trial was included in the independent function. Initial weight, digestible energy intake and their interaction accounted for 55.9% of the variation in total gain and 73.1% of the variation in hot carcass weight. According to the authors, initial weight was generally the most important independent variable for predicting selected dependent variables. They also indicated that the coefficients of determination for equations involving combinations of voluntary energy intake and gain in body weight for various lengths of time on feed increased with the length of time on feed.

Koch et al. (1963) has suggested that studies involving carcass composition are needed to determine feed efficiency measures for energy conversion or for edible portion instead of increase in body weight without regard to composition of gain. The authors indicated that gain adjusted for differences in feed consumption was considered the most accurate mathematical description of the cause and effect relationship and also resulted in the highest heritability estimate.

According to Meyer and Garrett (1967), the use of feed per pound of gain ratio can cause problems in interpretation. First, the measure of biological function is more properly either gain or feed intake because the ratio leaves the researcher with two unseparated biological response criteria which can only lead to uncertain conclusions. Second, in efficiency of feed utilization, the ratio of gain to feed intake infers that all feed consumed is utilized for body gain and ignores maintenance requirements. It also assumes that the origin passes through zero when gain is graphically plotted against feed consumption.

SOURCE OF DATA

Production and carcass trait data were collected from two groups of individually fed steers. Group one was fed in 1968 and group two in 1970. The 1968 steers were marketed at one of seven weight classes from approximately 386 to 522 kg at intervals of approximately 22.7 kg. The 1970 steers were marketed at one of four weight classes from approximately 386 to 522 kg at intervals of approximately 45 kg. An analog temperature computer was used to measure temperature and calculate heat loss of the 1970 steers. Two experiments were used to evaluate sources of variation associated with the temperature computer and compare temperatures and heat losses with increasing animal weight. Experiment one examined the effects of measurement periods within day, changes occurring over the summer and sire group differences of substitute steers. Experiment two examined weight class, period and breed of sire differences of the steers assigned to the four weight classes. Data from experiment two were used in combination with production data to estimate the energy utilization during the three intervals between classes and also to seek explanations for changes of carcass composition occurring during the same intervals.

Since the temperature computer data were collected only on the 1970 group and there were other differences between management practices and experimental technique, the 1968 and 1970 groups were considered as separate experiments.

The 1968 trial consisted initially of 31 Hereford steer progeny of two sires. These steers were born and raised on a private ranch in

South Dakota and, prior to being purchased by the University in March, these steers had been wintered on a high roughage ration. The steers were implanted with 24 mg of diethylstilbestrol on April 5, 1968. An initial shrunk weight was taken on April 9, 1968, the morning the steers were started on individual self feeders. The steers were allowed *ad libitum* feed for approximately 4 hours every morning. During the remainder of the time they were allowed free access to water, salt and mineral. The ration consisted of 60% ground yellow corn, 16% oats, 4% soybean oil meal (44%) and 20% ground alfalfa hay. According to values given by Crampton and Harris (1969), the ration contained 11.9% protein and 2583.6 kcal per kg of metabolizable energy.

The steers were stratified within sire on the basis of initial weight and were randomly allotted to one of seven weight classes. As one carcass was lost in the packing plant and another steer was removed because of sickness, only 29 steers completed the trial. The sire and weight class distribution for those steers which successfully completed the trial are shown in table 1.

The steers were weighed regularly at 28-day intervals in the early part of the feeding period and at intervals of 14 and 7 days as the steers approached their assigned weight class. When a steer's filled weight was at least 13 kg above his assigned weight, he was shrunk overnight without feed or water and a shrunk weight was taken prior to being loaded for market. All steers were trucked to Huron, South Dakota, and slaughtered at the Armour packing plant.

TABLE 1. SIRE AND WEIGHT CLASS DISTRIBUTION FOR 1968 TRIAL

	Weight class (kg)							Sire
Sire	386	408	431	454	476	499	522	total
019	3	3	3	2	3	2	2	18
005	1	2	1	1	2	2	2	11
Total	4	5	4	3	5	4	4	29

Carcass measurements and Federal Graders' estimates were obtained approximately 48 hours after slaughter. The right side of each carcass was shipped back to the SDSU Meat Laboratory where it was separated into edible portion, trimmed fat and removed bone components. Details concerning the carcass traits will be presented in a later section.

The 1970 trial consisted initially of 31 crossbred steer progeny of two Hereford and two Angus sires. These steers were born and raised until two weeks after weaning at the Newell Experiment Station. They arrived at Brookings on December 5, 1969, and were group fed until they were placed on individual self feeders on January 6, 1970. These steers were implanted with 24 mg of diethylstilbestrol on December 31, 1969, and reimplanted with 24 mg of diethylstilbestrol on April 11, 1970. The ration contained 60% ground yellow corn, 16% oats, 4% soybean oil meal (44%), 20% ground alfalfa hay and a premix containing vitamin A and Aureomycin. According to values given by Crampton and Harris (1969), the ration contained 11.9% protein and 2583.6 kcal per kg of metabolizable energy. The steers were allowed <u>ad libitum</u> feed for approximately 4 1/2 hours each morning. The remainder of the time the steers had free access to mineral, salt and water with the exception that water was shut off the evening prior to each weigh day. Shrunk weights and feed weigh backs were taken at 28-day intervals until June 9, 1970. After this date the weights and feed weigh backs were taken at 14-day intervals.

The initial progeny distribution of the two Angus and two Hereford sires was 7, 11, 4 and 9 steers per sire. These steers were stratified on the basis of the shrunk weight taken on December 9, 1969. As the objective was to have four weight classes, selection was practiced whenever a sire had more progeny than was evenly divided by four to minimize the variation within each group of four steers. One steer of each group of four was randomly allotted to one of the four weight classes. The resulting allotment consisted of three steers of each breed of sire or a total of six steers in each weight class. In addition, there were three extra steers for each Angus sire and one extra Hereford sired steer.

However, due to sickness (hardware disease, founder and generally poor performance) and difficulty in obtaining temperature computer measurements on one of the steers, all cells were not filled when the study was completed. Substitutions were made where it was possible without significantly affecting the initial weight. The sire and weight class distribution which was analyzed for production traits, carcass traits and measurements of temperature computer experiment two is presented in table 2.

TABLE 2. SIRE AND WEIGHT CLASS DISTRIBUTION OF 1970 STEERS

Breed	Sire	Weight class (kg) 386	431	476	522	Total
Hereford	364	1	1	1	1	4
Hereford	550	2	2	1	1	6
Angus	47	1	1	1	1	4
Angus	85	2	2	2	1	7
Total		6	6	5	4	21

Temperature Computer Measurements

According to Brookline Instruments (1968), the temperature computer had been used to monitor temperature and heat loss of humans. The main advantage of this instrument was that it did not require elaborate controlled environmental facilities. This instrument functioned like an analog computer to calculate heat loss using combinations of manually set factors and the temperatures sensed directly by the instrument. The eight individual skin temperatures, mean skin, mean body, rectal and ambient temperature could be displayed one at a time by adjusting the selector knob. The kcal of heat loss per hour was displayed on another meter. This instrument appeared to be a means of measuring the heat loss of steers raised in a near normal or conventional environment.

A number of preliminary measurements were taken on the substitute steers of sire 85 to examine the most desirable length of measurement time and to establish procedures which would fit the available facilities. The results of this preliminary work indicated that a one hour period of measurement with a one-half hour period between steers for preparation would best fit the objectives and the facilities. All measurements were taken in a room equipped with an air conditioner to keep the temperature below 24 C. Ambient temperature, time of day when the measurements were taken and the effects of feeding were potential sources of variation. Each measurement day was divided into six measurement periods as shown in table 3.

TABLE 3. PERIODS WITHIN MEASUREMENT DAY

Measurement period	Approximate time of day	Condition of steer
1	6:00 - 7:00	Shrunk
2	7:30 - 8:30	Shrunk
3	9:00 - 10:00	Shrunk
4	10:30 - 11:30	Filled
5	12:00 - 13:00	Filled
6	13:30 - 14:00	Filled

Experiment one consisted of a series of measurements taken from June until September on the two groups of Angus sired substitute steers. The purpose of this experiment was to evaluate the effects of measurement period within the day and also to evaluate changes with growth or measurement time during the summer. As the steers were originally substitutes or steers not allotted to the weight classes, considerable variation existed both within and between the two sire groups. Because of this variation the sire comparisons were not as meaningful. However, this variation should not alter the usefulness of repeated measurement comparisons and also, if adverse effects upon performance occurred, the outcome of the weight constant phase of the study would not be affected.

The basic procedure was that the three steers of sire 87 were measured two times each on day one and the three steers of sire 47 were measured two times each on day two of each measurement time period during the summer. Each steer was measured in one of the periods (1 to 3) before feeding and in the same order in one of the periods (4 to 6) after feeding. The steers were rotated in the periods within day positions such that over the total of six measurement times during the summer each steer was measured two times in each period. The interval between measurement times during the summer ranged from two to four weeks.

Experiment two included the temperature computer measurements taken on the steers originally assigned to weight classes. The effects of feeding and the time of day when the measurements were taken were potential sources of variation. Therefore, only one slaughter steer was measured on a single day. Each slaughter steer was measured in period one after an overnight shrink without access to either feed or water and also after feeding in the last measurement period of the day. The steers were stratified on the basis of initial weight within sire and the six groups were designated as sire groups. The periods between the first and last measurement period of each day were used for the measurement of any remaining steers of the sire groups. All weight constant steers were measured on a preliminary measurement day prior to the marketing of any steers. In addition, any remaining steers of the original sire group of four steers were measured whenever a steer of that group reached the designated weight class.

Since the number of steers remaining in a sire group was reduced by one each time a steer was slaughtered, there were a number of missing cells and thus some of the possible interactions could not be computed if all data were included in the analysis. Examination of the data suggested that after adjustment for ambient temperature differences there were no differences between readings taken on the remaining steers and on the slaughter steer. Therefore, the analysis included only the comparisons of the two periods of measurements taken on each of the steers prior to slaughter. The comparisons of energy utilization between weight class intervals were calculated using the heat loss data collected from these steers.

The biweekly work schedule is shown in table 4. Whenever any weight constant steer reached the assigned weight class plus at least 4 kg on the biweekly Tuesday weigh day, all steers of that measurement group were clipped and shaved and measured on one of the available measurement days. The steers were slaughtered at the John Morrell plant in Sioux Falls, South Dakota. Plant carcass data and Federal Grader estimates were collected approximately 24 hours after slaughter. The right side of each carcass was separated into edible portion, trimmed fat and removed bone in the SDSU Meat Laboratory after an aging period of 10 days after slaughter.

TABLE 4. BIWEEKLY WORK SCHEDULE

Day	Activity
Monday	(1) Weigh back feed in the afternoon; shut off water at 7:30 p.m.
Tuesday	(2) Weigh steers at 8:00 a.m.; clip and shave steers to be measured during the week during the afternoon.
Wednesday	(3) Available for measuring weight constant steers.
Thursday	(4) Available for measuring weight constant steers.
Friday	(5) Available for measuring weight constant steers.
Saturday	(6) Available for measuring weight constant steers.
Sunday	(7) Available for measuring weight constant steers. Weigh back feed and shut off water at 5:30 p.m. for steers going to market Monday morning.
Monday	(8) Obtain shrunk market weight at 6:30 a.m. Truck steers to Sioux Falls for slaughter that morning. Clip and shave substitute steers in the afternoon.
Tuesday	(9) Collect plant carcass data in the morning.
Wednesday	(10) Measure sire group 85 in periods 1 to 6.
Thursday	(11) Measure sire group 47 in periods 1 to 6.

Preparation Prior to Measuring. The temperature computer was equipped with eight skin temperature probes. Eight areas or temperature regions were determined in preliminary work during 1968 and 1969. The approximate temperature regions and locations of the eight probes are shown in figure 1. An area approximately 5 cm^2 near the center of each of the eight regions was clipped and shaved at least 18 hours prior to being measured with the temperature computer. The time interval between shaving and measurement was dependent upon the number of steers going to market at a given time. When it was possible, days 1 and 5 of the five available days were not used.

The relative surface area factors for each probe were determined by the following steps:

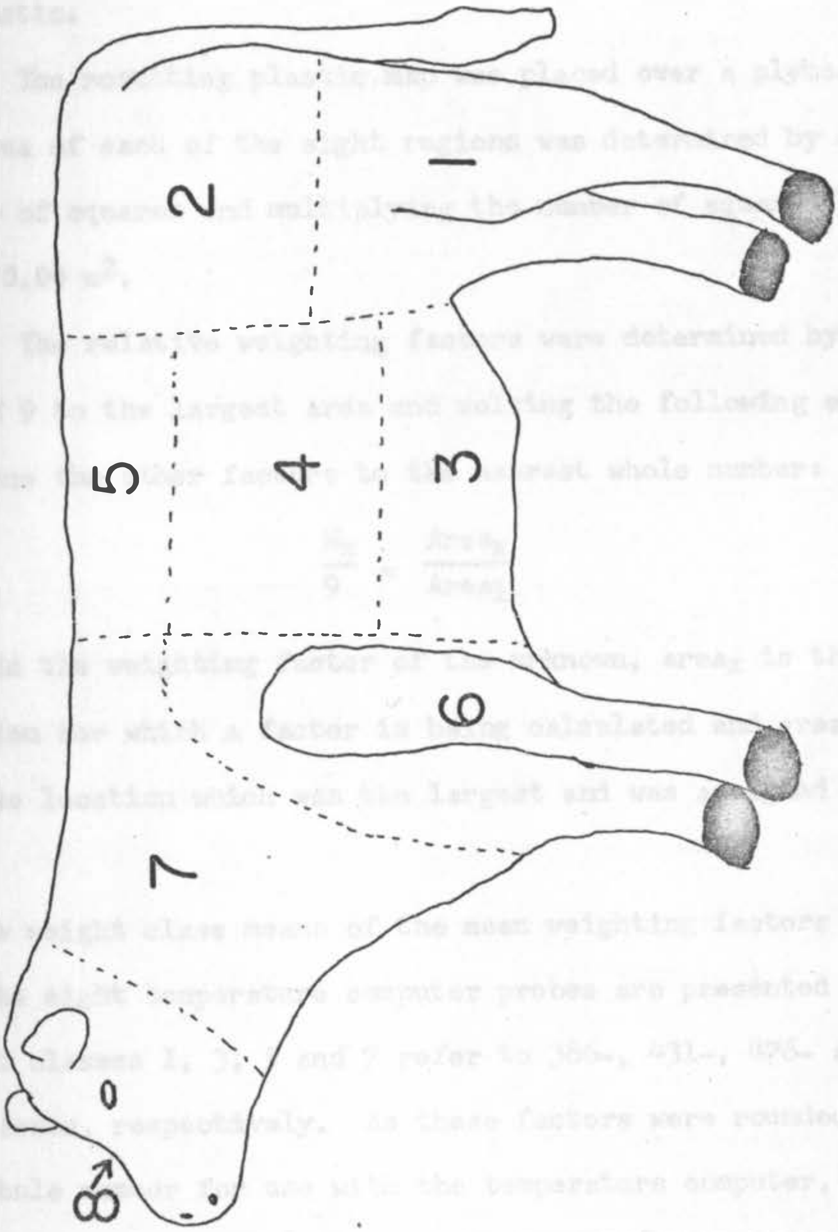

Figure 1. Location sites of the eight skin temperature probes.

1. A sheet of 4 mil plastic was placed over the body of the steer.

2. A magic marker was used to outline the respective regions on the plastic.

3. The resulting plastic map was placed over a plyboard grid and the area of each of the eight regions was determined by counting the number of squares and multiplying the number of squares by a factor of 0.04 m^2.

4. The relative weighting factors were determined by assigning a value of 9 to the largest area and solving the following equation to determine the other factors to the nearest whole number:

$$\frac{W_x}{9} = \frac{Area_x}{Area_1}$$

where W_x is the weighting factor of the unknown, $area_x$ is the area of the location for which a factor is being calculated and $area_1$ is the area of the location which was the largest and was assigned a value of 9.

The weight class means of the mean weighting factors used for each of the eight temperature computer probes are presented in table 5. The weight classes 1, 3, 5 and 7 refer to 386-, 431-, 476- and 522-kg weight classes, respectively. As these factors were rounded to the nearest whole number for use with the temperature computer, the values in the table suggest very little change from 386 to 522 kg. Weighting factors for probes 1, 3, 6, 7 and 8 did not change. Weighting factors

TABLE 5. WEIGHT CLASS MEANS OF THE MEAN PROBE WEIGHTING FACTORS

Probe	Weight class 1	3	5	7
1	5.8	5.8	5.8	6.3
2	5.8	6.2	6.4	6.8
3	9.0	9.0	9.0	9.0
4	7.3	8.5	8.2	8.5
5	2.2	2.8	3.0	3.0
6	6.0	6.1	6.2	5.8
7	6.3	5.8	6.0	5.8
8	3.3	3.0	3.0	3.0

for probes 4 and 5 changed between classes 1 and 3. Weighting factors for probe 2 changed between classes 5 and 7.

Steers which were to be measured the following morning were housed overnight to keep them dry. The steers were also without feed and water overnight. The steers which were measured in periods 1 to 3 were measured prior to feeding. Steers which were measured in periods 4 to 6 were allowed access to water prior to feeding at the regular time.

Measurement Procedure. An air conditioner was used to maintain the temperature of the measurement room at a temperature less than 24 C.

Each steer was restrained in the head gate of the squeeze chute. The skin probes were placed over the respective locations and were held in place with masking tape approximately 5 cm wide. Readings were recorded sequentially as follows: probes 1 to 8, ambient, rectal, mean body, mean skin and kcal of heat loss per hour every 5 minutes or a maximum of 13 sets of readings per hour. All readings were recorded on IBM computer punch sheets. Occasionally, interval readings were missed because the temperature probes were shaken off during restless activity of the steer. The author attempted to verify that all probes were firmly attached before recording the values. The temperature computer with the skin probes attached to the steer is shown in figure 2.

Temperature Computer Calculations

The Brookline Model 3 Temperature Computer sensed directly skin probes 1 to 8 and rectal and ambient temperatures. These values were used in combination with manually set values to solve equations for mean skin temperature, mean body temperature and kcal of heat loss per hour. The equations were:

1. $$T_{\text{mean skin}} = \frac{T_1W_1 + T_2W_2 + T_3W_3 + \ldots + T_8W_8}{W_1 + W_2 + W_3 + \ldots + W_8}$$

where T_1 to T_8 were the individual skin temperatures, and W_1 to W_8 were the individual weighting factors for each skin temperature.

2. $$T_{\text{mean body}} = (T_{\text{mean skin}})X + (T_{\text{rectal}})(1 - X)$$

where $T_{\text{mean skin}}$ was calculated as in equation 1, X is a proportioning factor equal to 0.25 as given by Brookline Instruments (1968). T_{rectal} was obtained with a probe.

Figure 2. Temperature computer leads attached on the steer.

3. $Q = H\,A\,(T_{mean\ skin} - T_{ambient})$

This equation was a modification of the Stefan Boltzmann equation, where Q = heat loss in kcal per hour, H = 5.5 and was the radiative and convection heat loss constant given by Brookline Instruments (1968) and A = radiating body surface area which was calculated using the formula of Brody (1928) in which surface area was equal to 0.124 plus kg of body weight raised to the 0.60 power. $T_{ambient}$ was sensed with the ambient probe. The values of "H" and "A" were set manually on the digital knobs on the control panel of the instrument.

Production Traits Measured and Evaluated

Days on Feed. This trait was the difference in number of days between the initial date of individually feeding the steers until the date of slaughter.

Initial Weight. All steers were weighed on the initial day on which they were given access to the individual self feeders.

Final Weight. A shrunk weight was taken prior to being loaded on the slaughter day.

Total Feed Consumption. This trait was the summation of all feed eaten during the time between initial and final weights.

Average Daily Feed Consumption. This trait was the total feed consumed divided by the days on feed.

Average Daily Gain. This trait was the kg of gain between initial and final weights divided by the days on feed.

Feed Per Kg of Live Weight Gain. This trait was calculated as the kg of feed consumed divided by the kg of live weight gain.

Feed Per Kg of Edible Portion. This trait was calculated by dividing the kg of feed consumed by the kg of edible portion.

Carcass Traits Measured and Evaluated

Kg of Edible Portion. This trait was equal to the summation of all individual retail cuts and lean trim from the right side of the carcass multiplied by two. The retail cuts were closely trimmed to about 0.6 to 0.7 cm external fat and were practically boneless except for a small amount of bone in the rib and loin cuts.

Percent Edible Portion. This trait was the kg of edible portion divided by the summation of kg of edible portion, trimmed fat and removed bone.

Kg of Trimmed Fat. This trait consisted of the summation of the trimmed fat from the right side multiplied by two.

Percent Trimmed Fat. This trait was the kg of trimmed fat divided by the summation of kg of edible portion, trimmed fat and removed bone.

Kg of Removed Bone. This trait was the summation of the bone removed from the right side multiplied by two.

Percent Removed Bone. This trait was the kg of removed bone divided by the summation of the kg of edible portion, trimmed fat and removed bone.

Kg of Kidney, Pelvic and Cod Fat. This trait was the summation of the kidney fat, pelvic and cod fat removed from the right side prior to cutting the carcass into wholesale cuts multiplied by two.

Lean Firmness. A subjective evaluation of the firmness of the muscle at the 12th rib, ranging from extremely soft to very firm, coded from 1 to 7, respectively, was involved with this trait. A representative of the U.S.D.A. Meat Grading Service made the evaluation.

Lean Color. A subjective evaluation of the relative color of muscle at the 12th rib, ranging from very dark red to dark pink, coded from 1 to 7, respectively, made up this trait. This evaluation was also made by a representative of the U.S.D.A. Meat Grading Service.

Marbling. An estimate of the intramuscular fat deposition of the *longissimus dorsi* muscle at the 12th rib was made by a representative of the U.S.D.A. Meat Grading Service using classifications from devoid to extremely abundant, coded from 1 to 12, respectively.

Maturity. A representative of the U.S.D.A. Meat Grading Service made a subjective estimate of the relative physiological age of the animal based equally on the extent of bone calcification, particularly in the dorsal thoracic region, and on the color of the lean. Twelve continuous subjective classifications were possible, with the oldest appearing carcasses assigned a coded score of 24.

Ribeye Area. This trait was determined by placing a plastic grid over the 12th ribeye muscle and counting the area under the grid.

Fat Thickness. A single measurement of rind thickness was taken at a position three-fourths the length of the ribeye muscle from the chine bone end and perpendicular to the outside surface of fat.

Dressing Percent. This trait was determined by dividing the chilled carcass weight by the final weight.

Carcass Grade. This trait was estimated by a representative of the U.S.D.A. Meat Grading Service using a coding system where 17 represented average good, 20 represented average choice and 23 represented average prime.

Comparative Energy Utilization Traits

Metabolizable Energy Intake. This trait was calculated as the kg of average feed intake during the intervals between weight classes multiplied by 2.5836 Mcal.

Temperature Computer Heat Loss Per Day. This trait was equal to the average hourly heat loss per hour between successive weight classes multiplied by 24.

Energy in Gain. The formula of Lofgreen and Garrett (1968) states that net energy for gain was equal to $(52.72_g + 6.84_g^2)(W_{kg}^{0.75})$, where g was equal to the average daily gain between each weight class interval.

Activity and/or Unaccounted for Energy. This trait was equal to the calculated metabolizable energy minus the summation of the temperature computer heat loss per day and the energy in gain.

STATISTICAL METHODS

Temperature Computer Data

Examination of the readings taken every 5 minutes suggested very little variation within the maximum of 13 readings taken each hour. These values were averaged and examination of the very small standard deviations suggested that this average value would be a good estimate of the temperature computer measurements for each measurement hour. Examination of the data also suggested that varying ambient temperatures tended to influence the surface skin temperature measurements.

As this experiment was conducted with the steers raised in as near a normal or conventional manner as possible with only the use of an air conditioner to prevent extremely high temperatures, considerable variation in ambient temperature occurred. From the standpoint that the animals are normally raised in similar conditions, this variation should not alter the examination of heat loss with respect to normal production and carcass traits. However, the relative effects should be evaluated prior to comparisons such as breed, sires, weight classes and period or time of measurement. The relative effects of varying ambient temperatures might also be useful for examination of the thermo-regulatory functions of the various body parts.

As the temperature computer experiment involving the extra steers during the summer months was conducted over a relatively narrow range of ambient temperatures and the weight class measurements were taken over a relatively wide range of ambient temperatures, regression coefficients were calculated separately for each experiment.

First and second degree polynomial regressions were calculated to determine the effects of changing ambient temperature upon skin temperatures. The significance of the second degree or quadratic term was determined by dividing the improvement in total sums of squares by the deviations about regression. The linear or first degree regression coefficient indicated the expected change in the dependent temperature computer measurement for each 1 C change in the independent ambient temperature. The combined effects of the first and second degree or linear and quadratic regression coefficients described the expected response in the dependent temperature computer measurement with changing independent ambient temperature.

Regression coefficients were computed and are presented in later sections for each of the eight skin probes, the rectal probe, mean skin and mean body temperature.

Regression equations and direct adjustment procedures for the effects of ambient temperature upon heat loss were not presented. Rather than using a direct adjustment procedure for the heat loss obtained with the analog computer, an indirect procedure was used. The mean skin temperature was adjusted for ambient temperature and the heat loss equation was solved by the digital computer. The reason for using this method was that surface area used in the equation was a function of growth rather than ambient temperature. In addition, the steers of the lower weight classes were marketed during periods of higher ambient temperature than were the steers of the heavier classes. Therefore, because of the confounding of surface area and ambient temperature and also the fact that the mean skin temperature was the variable affected by ambient temperature, the indirect adjustment for ambient effects upon heat losses was used.

Another advantage of using this method of adjustment was that the substitution of a one for surface area would result in the heat loss per unit of surface area and thus the comparison of heat loss between different size animals could be made independent of size effects. Calculated in this manner heat loss was a function of only the radiation and convection factor multiplied by the difference between mean skin and ambient temperature.

The temperature computer measurements of the eight skin probes, rectal probe and mean skin and mean body temperatures were adjusted for significant linear and/or quadratic effects. The general model for the equation used to adjust the temperature computer traits was:

$$Y_a = Y_o - b(X_o - \overline{x}) - c(X_o^2 - \overline{x}^2)$$

where Y_a is equal to the adjusted dependent variable, Y_o is equal to the unadjusted observation, b is the linear regression coefficient, X is the observed X or independent variable, $\overline{x}$ is the mean of the independent variable, c is the quadratic regression coefficient, X_o^2 is the observed independent variable squared and $\overline{x}^2$ is the mean of the squares of the independent observations.

After adjustment to the experimental mean ambient temperature, the temperature computer measurements were analyzed by analysis of variance. The main effects included six measurement periods within measurement day, two sire measurement groups and six measurement times during the summer. Assuming all classifications were fixed, the model for experiment one was:

$Y_{ijkl} = u + P_i + M_j + S_k + (PM)_{ij} + (PS)_{ik} + (MS)_{jk} + (PMS)_{ijk} + e_{ijkl}$

where Y_{ijkl} is the observation on the lth animal from the kth sire on the jth measurement time in the ith period, u is the general mean, P_i is the effect common to all animals in the ith period, M_j is the effect common to all animals in the jth measurement time, S_k is the effect common to all animals from the kth sire, $(PM)_{ij}$ is the interaction of the ith period and the jth measurement time, $(PS)_{ik}$ is the interaction of the ith period and the kth sire, $(MS)_{jk}$ is the interaction of the jth measurement time and the kth sire, $(PMS)_{ijk}$ is the interaction of the ith period with the jth measurement time and the kth sire and e_{ijkl} is the effect peculiar to the ijklth animal causing it to deviate from its expected performance in the kth sire group on the jth measurement time and in the ith period. The analysis of variance for the model is presented in table 6.

TABLE 6. ANALYSIS OF VARIANCE FOR TEMPERATURE COMPUTER EXPERIMENT ONE

Source of variation	Degrees of freedom	Mean squares expectations
Period	5	$\sigma^2w + 1\ \sigma^2a{:}pms + 12\ \sigma^2p$
Measurement time	5	$\sigma^2w + 1\ \sigma^2a{:}pms + 12\ \sigma^2m$
Sire group	1	$\sigma^2w + 1\ \sigma^2a{:}pms + 36\ \sigma^2s$
PM	25	$\sigma^2w + 1\ \sigma^2a{:}pms + 2\ \sigma^2pm$
PS	5	$\sigma^2w + 1\ \sigma^2a{:}pms + 6\ \sigma^2ps$
MS	5	$\sigma^2w + 1\ \sigma^2a{:}pms + 6\ \sigma^2ms$
PMS	25	$\sigma^2w + 1\ \sigma^2a{:}pms + 1\ \sigma^2pms$

The main effects of temperature computer experiment two included four weight classes, two measurement periods on each steer, two breeds of sire and two sires within each breed of sire. Assuming all classifications were fixed, the model was:

$$Y_{ijklm} = u + W_i + P_j + B_k + S_l{:}B_k + (WP)_{ij} + (WB)_{ik} + (PB)_{jk} + e_{ijklm}$$

where Y_{ijklm} is the observation on the mth animal from the lth sire within the kth breed in the jth measurement period and ith weight class, u is the general mean, W_i is the effect common to all animals in the ith weight class, P_j is the effect common to all animals measured in the jth period, B_k is the effect common to all animals of the kth breed, $S_l{:}B_k$ is the effect common to all animals of the lth sire within the kth breed, $(WP)_{ij}$ is the interaction of the ith weight class and the jth measurement period, $(WB)_{ik}$ is the interaction of the ith weight class and the kth breed, $(PB)_{jk}$ is the interaction of the jth period and the kth breed and e_{ijklm} is the effect peculiar to the ijklmth animal causing it to deviate from its expected performance in the lth sire within the kth breed measured in the jth period and of the ith weight class. The analysis of variance for the model is presented in table 7.

TABLE 7. ANALYSIS OF VARIANCE FOR TEMPERATURE COMPUTER EXPERIMENT TWO

Source of variation	Degrees of freedom	Mean square expectations
Weight class (W)	3	$\sigma^2 w + 1\ \sigma^2 a{:}wpbs + 4\ \sigma^2 w$
Period (P)	1	$\sigma^2 w + 1\ \sigma^2 a{:}wpbs + 8\ \sigma^2 p$
Breed of sire (B)	1	$\sigma^2 w + 1\ \sigma^2 a{:}wpbs + 8\ \sigma^2 b$
Sire:breed (S:B)	2	$\sigma^2 w + 1\ \sigma^2 a{:}wpbs + 8\ \sigma^2 s{:}b$
WP	3	$\sigma^2 w + 1\ \sigma^2 a{:}wpbs + 2\ \sigma^2 wp$
WB	3	$\sigma^2 w + 1\ \sigma^2 a{:}wpbs + 2\ \sigma^2 wb$
PB	1	$\sigma^2 w + 1\ \sigma^2 a{:}wpbs + 4\ \sigma^2 pb$
Residual	27	$\sigma^2 w + 1\ \sigma^2 a{:}wpbs$

Production and Carcass Traits

Assuming that all classifications were fixed, the model for the 1968 production and carcass traits was:

$$Y_{ijk} = u + W_i + S_j + (WS)_{ij} + e_{ijk}$$

where Y_{ijk} is the observation on the kth animal from the jth sire and ith weight class, u is the general mean, W_i is the effect common to all animals in the ith weight class, S_j is the effect common to all animals from the jth sire, $(WS)_{ij}$ is the interaction of the ith weight class and the jth sire and e_{ijk} is the effect peculiar to the ijkth animal causing it to deviate from expected performance of the jth sire and the ith weight class. The analysis of variance for the model is presented in table 8.

TABLE 8. ANALYSIS OF VARIANCE FOR 1968
PRODUCTION AND CARCASS DATA

Source of variation	Degrees of freedom	Mean square expectations
Weight class	6	$\sigma^2 w + 1\ \sigma^2 a{:}sw + 2\ \sigma^2 w$
Sire	1	$\sigma^2 w + 1\ \sigma^2 a{:}sw + 7\ \sigma^2 s$
WS	6	$\sigma^2 w + 1\ \sigma^2 a{:}sw + 1\ \sigma^2 sw$
Residual	16	$\sigma^2 w + 1\ \sigma^2 a{:}sw$

Assuming that all classifications were fixed, the model for the 1970 production and carcass traits was:

$$Y_{ijkl} = u + W_i + B_j + S_k{:}B_j + (WB)_{ij} + e_{ijkl}$$

where Y_{ijkl} is the observation on the l<u>th</u> animal from the k<u>th</u> sire within the j<u>th</u> breed and in the i<u>th</u> weight class, u is the general mean, W_i is the effect common to all animals in the i<u>th</u> weight class, B_j is the effect common to all animals of the j<u>th</u> breed, $S_k{:}B_j$ is the effect common to all animals of the k<u>th</u> sire within the j<u>th</u> breed, $(WB)_{ij}$ is the interaction of the i<u>th</u> weight class and the j<u>th</u> breed of sire and e_{ijkl} is the effect peculiar to the ijkl<u>th</u> animal causing it to deviate from its expected performance in the k<u>th</u> sire within the j<u>th</u> breed and the i<u>th</u> weight class. The analysis of variance for the model is presented in table 9.

TABLE 9. ANALYSIS OF VARIANCE FOR 1970
PRODUCTION AND CARCASS TRAITS

Source of variation	Degrees of freedom	Mean square expectations
Weight class	3	$\sigma^2w + 1\ \sigma^2a{:}sbw + 4\ \sigma^2w$
Breed	1	$\sigma^2w + 1\ \sigma^2a{:}sbw + 4\ \sigma^2b$
S:B	2	$\sigma^2w + 1\ \sigma^2a{:}sbw + 4\ \sigma^2s{:}b$
WB	2	$\sigma^2w + 1\ \sigma^2a{:}sbw + 1\ \sigma^2wb$
Residual	12	$\sigma^2w + 1\ \sigma^2a{:}sbw$

RESULTS AND DISCUSSION

Temperature Computer Experiment One

Two sire groups of three steers each which had been designated as substitutes at allotment time were utilized to evaluate period during the day, measurement time during the summer and sire group differences.

First and second degree polynomial regressions were calculated to determine the effects of changing ambient temperature on animal temperatures. The significance of the second or quadratic term was tested by dividing the improvement in total sums of squares by the deviations about regression. The significant regression equations for the regression of animal temperatures upon ambient temperature are presented in table 10.

The rectal temperature was the only measurement which did not have a significant regression upon ambient temperature. Probes 4 and 5 of the side and back locations were the only probes with significant quadratic regression coefficients. All other measurements had highly significant linear regression coefficients.

Examination of the magnitude of the regression coefficients suggested that various parts of the body responded differently with ambient temperature changes and supported thermoregulatory functions discussed by Whittow (1962) and Blaxter (1962). The similar magnitudes of the regression coefficients of probes 1 and 6 suggested that the lower limbs responded similarly to changes in ambient temperature. The similar values obtained for probes 7 and 8 suggested regional

TABLE 10. REGRESSION EQUATIONS OF ANIMAL TEMPERATURES (Y) ON AMBIENT (X) IN EXPERIMENT ONE

Temperature	Intercept	Regression coefficients	
		Linear	Quadratic
Probe 1	28.08	0.3067**	a
Probe 2	26.18	0.3492**	a
Probe 3	26.53	0.3912**	a
Probe 4	- 5.89	3.4152**	-.0704**
Probe 5	-12.82	4.1742**	-.0904**
Probe 6	28.68	0.2973**	a
Probe 7	20.26	0.6534**	a
Probe 8	18.66	0.6484**	a
Rectal	---	a	a
x body	35.38	0.1153**	a
x skin	25.19	0.4394**	a

** $P < .01$.

[a] Indicates that the regression coefficient was not significant at the .05 level.

similarities of body parts in response to changes of ambient temperature. The differences between the regions of the body were thought to be part of the thermoregulatory mechanism for the maintenance of body temperature.

The temperature computer measurements were adjusted to the mean ambient temperature of 21.5 C. The period means of the adjusted temperature computer measurements are presented in table 11.

The rectal temperature was the only measurement which was significantly different for periods within the measurement day.

TABLE 11. PERIOD MEANS OF ADJUSTED[a] TEMPERATURE COMPUTER MEASUREMENTS WITH F-TESTS OF SIGNIFICANCE

Measurement	Period 1	2	3	4	5	6	F value
Probe 1, °C	34.87	35.11	34.60	34.63	34.52	34.32	0.8556
Probe 2, °C	33.79	33.85	33.63	33.50	33.66	33.69	0.2311
Probe 3, °C	35.09	35.27	34.90	34.95	34.90	34.53	1.5822
Probe 4, °C	34.89	34.66	34.71	34.92	34.90	34.71	0.2763
Probe 5, °C	34.83	34.90	34.57	35.08	35.09	34.81	1.5901
Probe 6, °C	35.07	35.42	34.89	35.11	35.15	34.78	0.6622
Probe 7, °C	34.32	34.25	34.27	34.45	34.32	34.21	0.1699
Probe 8, °C	32.58	32.58	32.61	32.62	32.61	32.59	0.0053
Rectal, °C	38.62	38.64	38.87	38.71	38.58	38.84	3.1653*
$\bar{x}$ body, °C	37.82	37.85	37.97	37.87	37.76	37.87	0.7909
$\bar{x}$ skin, °C	34.75	34.85	34.55	34.70	34.52	34.37	1.7020
(x skin - 21.5), C	13.25	13.35	13.05	13.20	13.10	12.87	1.7020
Heat loss, kcal/hr/m^2	72.9	73.4	71.8	72.6	72.1	70.8	1.7020

* $P < .05$.

[a] All temperatures were adjusted to the mean ambient temperature of 21.5 C using regression coefficients presented in table 10.

Although the F value was significant, the small ranges between the rectal temperatures of the six periods suggested that this difference was not of practical importance. The higher temperatures occurred during periods 3, 4 and 6. Period 3 was during the normal feeding time and period 4 was about 1 1/2 hours after the steers were allowed access to the self feeders. Animals measured in period 3 of a given day were also measured in period 6. Therefore, the increased rectal temperature of these three periods could be attributed to the effects of delayed feeding and the ingestion of feed. However, as the changes were very small, the rise in temperature was probably not of practical importance.

None of the surface temperature measurements were significantly different between periods within the same day. In general, the F values were small. These results suggested that after adjustment for ambient temperature differences no important differences were detected in surface temperature measurements between periods within the measurement day.

The results obtained in this phase of the experiment suggested that in the future period differences would not be a factor in the comparison of surface temperatures of animals measured during the same day. However, due to the increased rectal temperature during periods around feeding time, these periods should be avoided.

The measurement time temperature means are presented in table 12. Examination of the values suggested that fluctuations had occurred between measurement times. The lower value of probe 1 during time 5 was probably a function of technical difficulties rather than a

TABLE 12. MEASUREMENT TIME MEANS OF ADJUSTED[a] TEMPERATURE COMPUTER MEASUREMENTS WITH F-TESTS OF SIGNIFICANCE

Measurement	Measurement time 1	2	3	4	5	6	F value
Probe 1, °C	34.88	35.76	34.35	34.57	33.48	35.01	6.4966**
Probe 2, °C	34.00	32.13	34.15	34.57	34.53	32.74	15.6409**
Probe 3, °C	34.79	34.66	35.31	34.79	35.38	34.70	2.6996*
Probe 4, °C	34.85	34.54	34.94	34.71	35.06	34.69	0.7303
Probe 5, °C	35.05	34.77	34.69	34.96	34.92	34.88	0.7155
Probe 6, °C	35.38	34.84	35.38	35.16	34.88	34.77	1.019
Probe 7, °C	34.36	34.26	34.48	34.20	34.54	34.00	1.000
Probe 8, °C	32.33	32.87	33.18	31.95	33.14	32.12	5.1787*
Rectal, °C	38.84	38.61	38.67	38.66	38.71	38.77	1.5762
$\bar{x}$ body, °C	37.94	37.78	37.97	37.87	37.93	37.65	2.3986
$\bar{x}$ skin, °C	34.68	34.52	34.91	34.68	34.77	34.25	3.1321*
(x skin - 21.5), C	13.18	13.02	13.41	13.18	13.27	12.75	3.1321*
Heat loss, kcal/hr/m^2	72.5	71.6	73.7	72.5	73.0	70.1	3.1321*

* $P < .05$.
** $P < .01$.
[a] The temperature computer measurements were adjusted to the experimental mean ambient temperature of 21.5 C using the regression coefficients presented in table 10.

physiological difference as this probe required adjustment after time 5.

In general with the exception of probe 1, all surface temperatures were lower for measurement time 6 than for any other time. The decreased temperatures during the last measurement time were in general agreement with Stewart and Shanklin (1958) who reported that surface temperatures of heifers raised in controlled environmental chambers decreased slightly with growth. The increased amount of fat and tissue insulation normally expected with increased time on feed could have been a contributing factor of the reduced surface temperature.

The relative growth patterns of each sire group and the mean of both groups are shown in figure 3. The growth patterns of both sire groups were similar with both groups exhibiting a rapid increase between times 5 and 6. This rapid increase in growth rate may have also been associated with the lower surface temperatures observed in time 6.

Sire means of temperature computer measurements are presented in table 13. Significant sire differences were observed for all probes except 2 and 5. There appeared to be no apparent explanation for this occurrence. Although highly significant differences were observed for sires, it should be acknowledged that this experiment was conducted with extra steers which were quite variable between groups. In addition, sires were confounded with the day the measurements were taken. The small size of the differences suggested that they might not be of

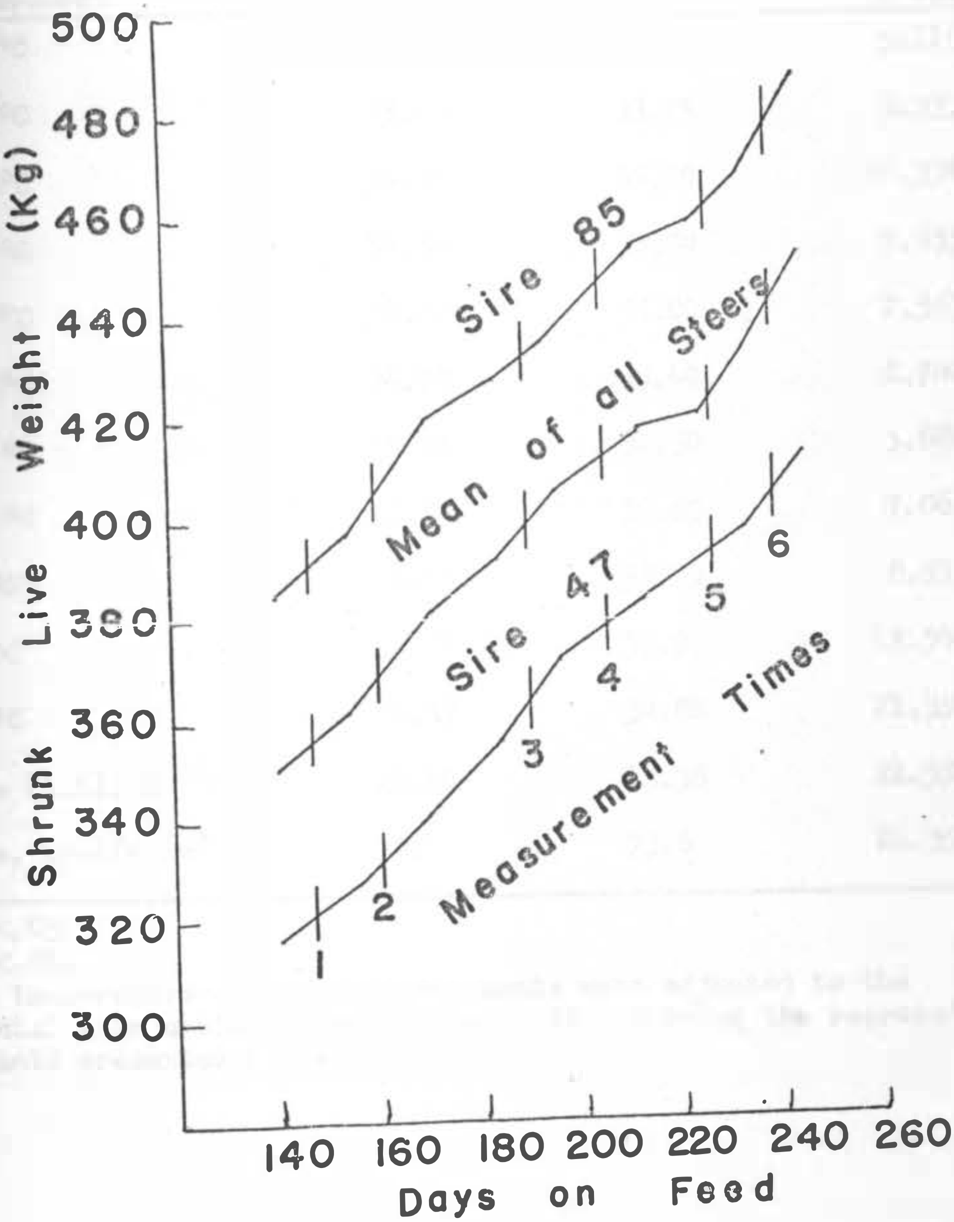

Figure 3. Relative growth patterns of the substitute steers with respect to measurement times 1 to 6 during the summer.

TABLE 13. SIRE GROUP MEANS OF ADJUSTED[a] TEMPERATURE COMPUTER MEASUREMENTS WITH F-TESTS OF SIGNIFICANCE

Measurement	Sire 47	Sire 85	F value
Probe 1, °C	34.40	34.95	5.1185*
Probe 2, °C	33.63	33.75	0.3338
Probe 3, °C	34.60	35.30	18.3346**
Probe 4, °C	34.56	35.04	7.05549*
Probe 5, °C	34.78	35.00	2.5637
Probe 6, °C	34.74	35.40	8.742**
Probe 7, °C	34.11	34.50	5.8801*
Probe 8, °C	32.34	32.85	7.064*
Rectal, °C	38.63	38.79	8.9324**
$\bar{x}$ body, °C	37.73	37.97	13.5475**
$\bar{x}$ skin, °C	34.39	34.88	21.3502**
(x skin - 21.5), C	12.89	13.38	21.3502**
Heat loss, kcal/hr/m²	70.9	73.6	21.3502**

* $P < .05$.
** $P < .01$.
[a] The temperature computer measurements were adjusted to the experimental mean ambient temperature of 21.5 C using the regression coefficients presented in table 10.

practical significance. Therefore, it should not be concluded that all phenotypic differences observed were genetic differences.

The results of experiment one suggested that ambient temperature significantly affected surface temperature but had no significant influence upon rectal temperature in an ambient temperature range of approximately 15 to 24 C with a mean of 21.5 C. After adjustment for ambient temperature, surface temperatures were not significantly different between periods within measurement day. Surface temperature decreased with growth or measurement time during the summer. The significant differences between sire groups might have been partly due to the extreme variation between the weights of the extra steers used in this experiment. Sire groups were also confounded with measurement day.

Temperature Computer Experiment Two

Each weight constant steer was measured in the first and last period of the measurement day during one of the five possible measurement days preceding each market day. As the market dates ranged from June 15, 1970, until December 21, 1970, considerable variation in environmental temperature occurred. First and second degree polynomial regressions were conducted to determine the effects of changing ambient temperature upon the animal temperature measurements. The significance of the second or quadratic term was tested by dividing the improvement in total sums of squares by the deviations about regression. The intercepts and regression coefficients for the highest degree polynomial regression equation which was significant for regression of animal temperature upon ambient are presented in table 14. The magnitudes of the coefficients were smaller than those of experiment one. A contributing factor for the lower values in this experiment was that experiment two had a range of ambient temperature from 4 to 24 C with a mean of 15.8 C, whereas the range of experiment one was only 15 to 24 C. The relative patterns appeared to be the same. Significant linear and quadratic regressions were found for probes 5, 6 and the rectal probe. All other measurements were significant only for the linear regression effects. The wider ambient temperature range was probably responsible for the fact that the rectal temperature was significantly affected by ambient temperature only in experiment two The larger magnitude of the regression coefficients of probes 7 and 8 suggested that these probes responded more to changes in ambient temperature. The regional similarities suggested similar responses to changes of ambient temperatures. Differences between regression coefficients of different parts suggested thermoregulatory functions for maintaining normal body temperature.

The graph of the regression of mean skin temperature upon ambient temperature is shown in figure 4. The regression line appeared to fit the data reasonably well. This graph might be useful for estimating the heat loss of steers in given environmental temperatures. The estimation of the heat loss could be done by modifying the heat loss equation presented by Brookline Instruments (1968). The modified equation would be as follows: $Q = A \times H \times (Y - X)$. In this equation Q is equal to the kcal of heat loss per hour, A is equal to the

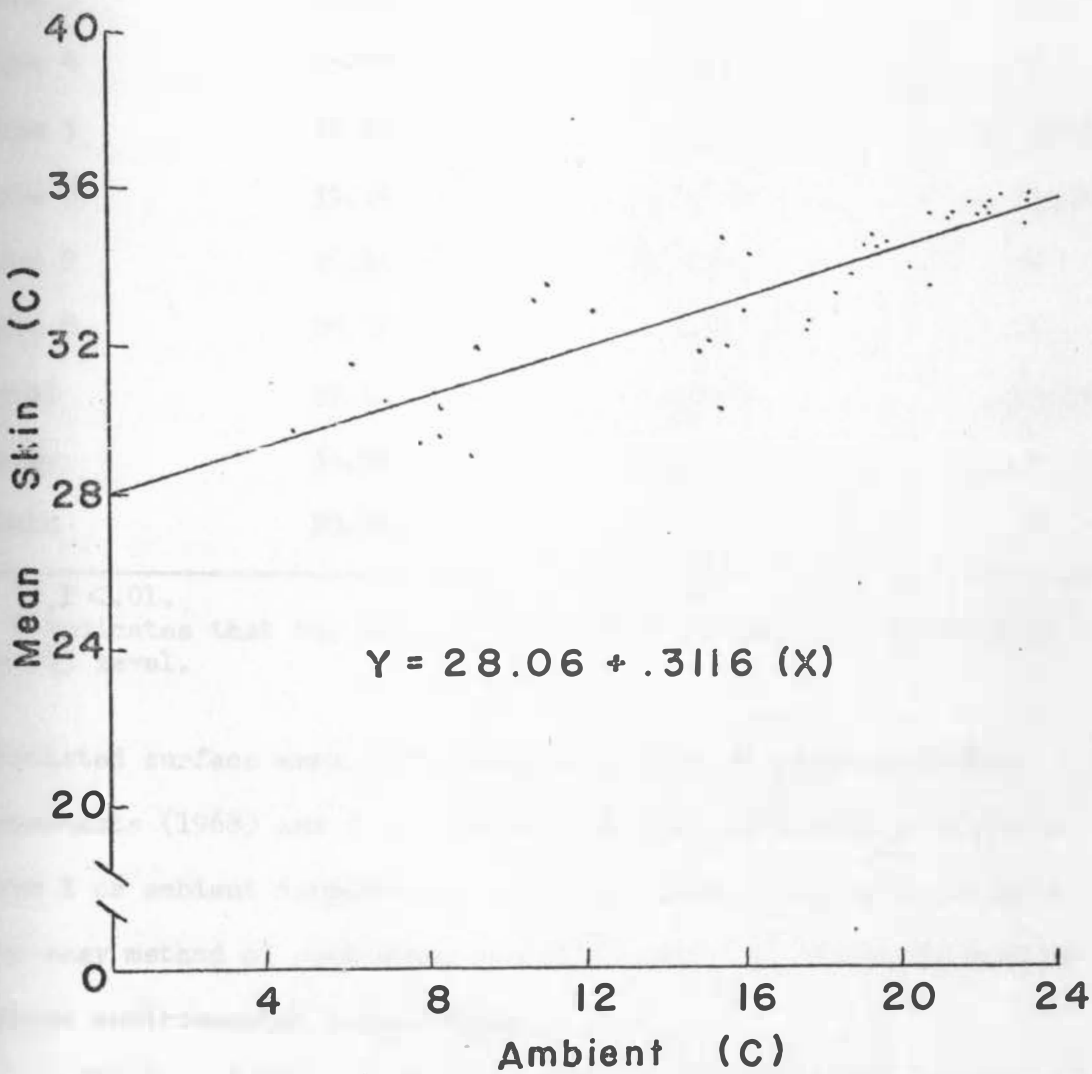

Figure 4. Regression of mean skin (y) on the ambient temperature (x).

TABLE 14. REGRESSION EQUATIONS OF ANIMAL TEMPERATURES (Y) ON AMBIENT (X) IN EXPERIMENT TWO

Temperature	Intercept	Regression coefficients Linear	Quadratic
Probe 1	29.15	0.2766**	a
Probe 2	29.05	0.2169**	a
Probe 3	29.23	0.2840**	a
Probe 4	28.75	0.2747**	a
Probe 5	29.58	-.1853**	0.0198**
Probe 6	33.19	-.3877**	0.0225**
Probe 7	26.10	0.3699**	a
Probe 8	24.36	0.3997**	a
Rectal	37.11	0.1880**	-.0051**
$\bar{x}$ body	35.90	0.0997**	a
$\bar{x}$ skin	28.06	0.3116**	a

** $P < .01$.

[a] Indicates that the regression coefficient was not significant at the .05 level.

calculated surface area, H is equal to 5.5 as given by Brookline Instruments (1968) and Y is the value on the regression line for a given X or ambient temperature. The use of this method would be a very easy method of estimating the heat losses of steers exposed to various environmental temperatures.

All temperature computer data were adjusted to the experimental mean ambient temperature of 15.8 C using the significant regression coefficients which were presented in table 14. The weight class means of adjusted temperature computer measurements with the F-tests of significance are presented in table 15. Weight classes 1, 3, 5 and 7 refer to the 386-, 431-, 476- and 522-kg weight classes, respectively. After adjustment to the experimental mean ambient temperature, no significant differences were detected between weight classes for temperature computer measurements. The F values were generally small for all measurements. Although there were no significant differences between weight classes, examination of the mean skin temperature suggested that the mean skin temperature increased slightly between classes 1 and 3 and further increased in class 5 but was lowest for class 7. Although the changes between classes were small, the reduction in surface skin temperature agrees with the reduction observed during the last measurement time of experiment one of this study and also with Stewart and Shanklin (1958) who indicated that surface temperature decreased with growth. The increased amount of fat and tissue insulation of weight class 7 could have been a factor involved in the lower surface temperature of this class.

The period and breed of sire means of temperature computer measurements are presented in table 16. The only surface temperature which was significantly different for periods and sires was probe 2 or the rump probe. A possible explanation for the fact that only probe 2 was significantly different between periods and breed of sire was that this probe was located on the rump which was very near the rectum. It was observed while recording the measurements that a defecation increased the temperature of probe 2. Therefore, the rectal influence

TABLE 15. WEIGHT CLASS MEANS OF ADJUSTED[a] TEMPERATURE COMPUTER MEASUREMENTS WITH F-TESTS OF SIGNIFICANCE

Measurement	Weight class 1	3	5	7	F value
Probe 1, °C	33.58	33.25	33.53	33.57	0.1471
Probe 2, °C	32.81	32.56	32.57	31.95	0.8655
Probe 3, °C	33.61	33.85	34.17	33.22	1.1164
Probe 4, °C	32.99	33.49	33.53	32.75	0.4620
Probe 5, °C	32.14	32.73	32.38	32.26	0.4542
Probe 6, °C	33.47	33.21	33.56	33.53	0.1347
Probe 7, °C	31.84	32.23	32.09	31.45	0.6780
Probe 8, °C	30.51	30.91	30.80	30.86	0.1594
Rectal, °C	38.64	38.61	38.61	38.56	0.1036
$\bar{x}$ body, °C	37.48	37.41	37.62	37.27	1.9684
$\bar{x}$ skin, °C	32.98	33.07	33.25	32.69	0.6822
(x skin - 15.8), C	17.18	17.27	17.45	16.89	0.6822
Heat loss, kcal/hr/m^2	94.49	94.99	95.98	92.90	0.6822

[a] The temperature computer measurements were adjusted to the experimental mean ambient temperature of 15.8 C using regression coefficients presented in table 14.

TABLE 16. PERIOD AND BREED OF SIRE MEANS OF ADJUSTED[a] TEMPERATURE COMPUTER MEASUREMENTS WITH F-TESTS OF SIGNIFICANCE

Measurement	Periods			Breed of sire		
	First	Last	F value	Hereford	Angus	F value
Probe 1, °C	33.21	33.76	1.6045	33.20	33.77	1.6938
Probe 2, °C	32.21	32.74	4.2489*	32.08	32.86	6.8057**
Probe 3, °C	33.57	33.85	0.6229	33.79	33.63	0.1907
Probe 4, °C	32.87	33.50	1.3577	33.06	33.32	0.2188
Probe 5, °C	32.27	32.49	0.3051	32.50	32.26	0.3353
Probe 6, °C	33.40	33.49	0.0384	33.06	33.83	2.7812
Probe 7, °C	31.63	32.17	1.8709	31.96	31.85	0.0670
Probe 8, °C	30.40	31.14	2.4179	31.08	30.46	1.6091
Rectal, °C	38.61	38.60	0.0070	38.68	38.53	2.1202
$\bar{x}$ body, °C	37.41	37.47	0.3484	37.46	37.43	0.1053
$\bar{x}$ skin, °C	32.81	33.18	1.9656	32.93	33.07	0.2813
($\bar{x}$ skin - 15.8), C	17.01	17.38	1.9656	17.13	17.27	0.2813
Heat loss, kcal/hr/m^2	93.56	95.59	1.9656	94.22	94.99	0.2013

* $P < .05$.
** $P < .01$.
[a] The temperature computer measurements were adjusted to the experimental mean ambient temperature of 15.8 C using the regression coefficients presented in table 10.

upon this probe could have been a contributing factor for this probe to be the only one which was significant. All surface temperatures were higher during the last measurement period. There appeared to be very little difference in the temperature computer measurements between breeds of sires.

The results of the second temperature computer experiment suggested that ambient temperature significantly affected all temperature computer measurements. After the temperature computer measurements were adjusted to the mean ambient temperature, no differences were observed for weight classes, first vs. last measurement period and breed of sire. The regression equation obtained for the regression of mean skin upon ambient temperature was presented for estimation of heat loss at different environmental temperatures.

The results of both experiments suggested that measurement periods within day would not be different after the measurements had been adjusted for ambient temperature differences. Therefore in future experiments, several slaughter steers could be measured on the same day rather than using separate measurement days and two measurements for each steer as was done in this experiment.

Production and Carcass Traits of the 1968 Steers

The 1968 steers were slaughtered at approximately 22.5 kg intervals from 386 to 522 kg. The weight classes 1, 2, 3, 4, 5, 6 and 7 indicated in the tables of this section refer to the 386-, 408-, 431-, 454-, 476-, 499- and 522-kg weight classes, respectively.

The market dates of the 1968 steers are presented in table 17. Although no statistical analysis was conducted on market dates, this information was presented so that the reader could observe the distribution of market dates. In general as expected most of the lighter weights were marketed at the earlier dates and more of the heavier weight classes were marketed near the end of the feeding period. However, in nearly all cases steers of more than one weight class were marketed on the same day.

TABLE 17. MARKET DATES OF THE 1968 WEIGHT CONSTANT STEERS

Date	Days on feed	Weight class 1	2	3	4	5	6	7
6-11-68	63		1	1				
7-3-68	85	2		2	1			
7-17-68	99		2					
7-24-68	106						1	
7-30-68	112	1					1	
8-5-68	118	1						
8-21-68	134		1			1		
9-11-68	155				1	1		
9-18-68	162			1	1	2	1	
10-8-68	182					1		2
10-29-68	203							1
11-13-68	218		1				1	1
Totals		4	5	4	3	5	4	4

The weight class means of production traits of the 1968 steers are presented in table 18. Significant differences between weight classes were observed for days on feed, final weight and total feed consumption. These traits were expected to be different by the very nature of a weight constant trial. With the exception of weight class 3, the actual final weight was generally 7 to 10 kg heavier than the assigned weight and the differences between actual and assigned weights were quite consistent for all other weight classes. There appeared to be considerable fluctuation in the total days on feed between weight classes. Normally one would not have expected that the average number of days on feed would be less for class 3 than for either classes 1 or 2. This fluctuation in the total days on feed was apparently due to sampling variation and also to variation in initial weight between weight classes. The adjustment of the total days on feed to the mean initial weight reduced the variation but did not remove all of the fluctuations and thus suggested that some of the fluctuations between weight classes in total days on feed were caused by sampling variation associated with the data collected from a small sample size.

With the exception of class 6, total feed consumption increased with the number of days on feed. Fluctuations were observed but no significant differences between weight classes were detected for average daily gain, average daily feed consumption, feed per kg of live weight gain and feed per kg of edible portion. The ratio of feed per kg of edible portion increased with increasing number of days on feed.

TABLE 18. WEIGHT CLASS MEANS OF PRODUCTION TRAITS OF THE 1968 STEERS WITH F-TESTS OF SIGNIFICANCE

Trait	Weight class							F value
	1	2	3	4	5	6	7	
Initial age, days	366	368	376	379	378	375	377	0.7591
Days on feed	106	132	87	122	157	150	196	4.0756*
Initial wt, kg	252.9	276.3	308.1	295.7	285.3	303.9	285.0	1.2758
Final wt, kg	397.3	417.8	433.6	465.3	486.1	507.5	528.8	354.7682**
Total feed, kg	772.4	967.8	666.8	957.0	1246.0	1380.6	1623.8	5.4496**
Avg daily gain, kg	1.38	1.19	1.48	1.47	1.29	1.41	1.25	0.9479
Avg daily feed consumption, kg	7.28	7.47	7.68	8.17	8.00	9.20	8.24	2.7616
Feed/live wt gain	5.4	6.6	5.2	5.6	6.3	6.7	6.7	1.4686
Feed/edible portion	5.1	5.8	4.0	5.4	7.1	7.1	8.0	2.5096

* $P < .05$.
** $P < .01$.

The weight class means of the carcass traits of the 1968 steers are presented in table 19. No significant differences between weight classes were observed for lean firmness, lean color, marbling, maturity or carcass grade. The generally small differences between each successive weight class as well as the range of the means from the high to low values also suggested little variation in these traits. Significant differences were found for ribeye area, fat thickness and dressing percent. With the exception of weight class 3, ribeye area increased with successive weight classes. With the exception of weight class 4, fat thickness increased with successive weight classes. Although fluctuation in dressing percent was present between the first three weight classes, dressing percent increased with each of the last four weight classes. These differences in dressing percent were probably associated with the number of days on feed, final weight and average amount of fat.

Significant differences between weight classes were observed for carcass composition traits expressed either as kg or as a percent of the carcass cutting weight. Examination of the values suggested that, although fluctuations occurred, percent edible portion and percent removed bone decreased while percent fat increased with increasing animal weight. The fluctuations between classes were probably functions of the opportunity for sampling error and biological variation present when only three to five animals represented a given weight class. In addition the determination of slaughter dates at periodic weigh dates on the basis of 22.7 kg intervals was subject to

TABLE 19. WEIGHT CLASS MEANS OF CARCASS TRAITS OF THE 1968 STEERS WITH F-TESTS OF SIGNIFICANCE

Trait	Weight class							F value
	1	2	3	4	5	6	7	
Lean firmness	4.5	4.6	4.2	4.5	4.4	4.3	4.8	0.1796
Lean color	5.0	4.3	5.1	5.0	4.8	4.8	4.8	0.6066
Marbling	3.0	3.2	3.5	3.2	3.8	4.0	4.2	1.1922
Maturity	24.0	24.0	24.0	24.0	23.8	23.8	23.2	2.6343
Ribeye area, cm^2	69.6	74.3	70.0	79.8	81.2	82.9	88.7	3.4904*
Fat thickness, cm	0.43	0.58	0.53	1.21	1.01	1.02	1.40	4.7955**
Dressing percent	56.3	59.1	57.0	58.5	58.6	59.8	61.0	6.6783**
Carcass grade	16.3	16.8	16.8	17.2	18.2	18.0	18.3	2.1892
Edible portion, kg	154.9	166.9	165.6	178.2	173.9	198.6	187.4	14.26**
Percent edible portion	72.9	70.9	71.4	69.0	65.7	68.3	62.1	7.3284**
Fat, kg	23.3	31.5	29.6	42.9	51.9	52.2	73.5	16.6024**
Percent fat	10.9	13.4	12.7	16.6	19.6	18.0	24.3	9.0161**
Bone, kg	34.3	37.1	36.9	37.2	39.0	39.9	41.1	4.3891**
Percent bone	16.2	15.7	15.9	14.2	14.7	13.8	13.6	5.4492**
Kidney and cod fat	6.5	7.0	7.3	8.3	9.0	10.0	10.8	7.6067**

* $P < .05$.
** $P < .01$.

variations in fill and might have also been associated with environmental conditions.

Fluctuations between successive weight classes also occurred when carcass composition traits were expressed in kg. The nature of these fluctuations can be observed when the relative growth of the edible portion, trimmed fat, removed bone and the summation of the kidney, pelvic and cod fat were plotted against carcass weight in figure 5. Both the kg of edible portion and trimmed fat increased in a straight line manner with increasing carcass weight for the first four classes. However, considerable fluctuation with alternating decreases and increases in edible portion and corresponding increases and decreases in trimmed fat occurred during the last three classes. The growth of the removed bone and the summation of the kidney, pelvic and cod fat increased slightly with increasing carcass weight.

The absolute decreases in the edible portion between successive weight classes were probably a function of sampling and biological variation associated with the small number of animals representing each point. However, the growth patterns supported the tendency for the occurrence of a plateau near the middle and an increased amount of edible portion near the end reported by Dinkel *et al.* (1969) with larger numbers of animals in both weight constant and time constant experiments. The objectives of the current experiment were to sample at intervals of 22.7 kg rather than at 45 kg and also to measure feed consumption. Although feed consumption may not have been the direct cause of the edible portion fluctuations, it was interesting to note

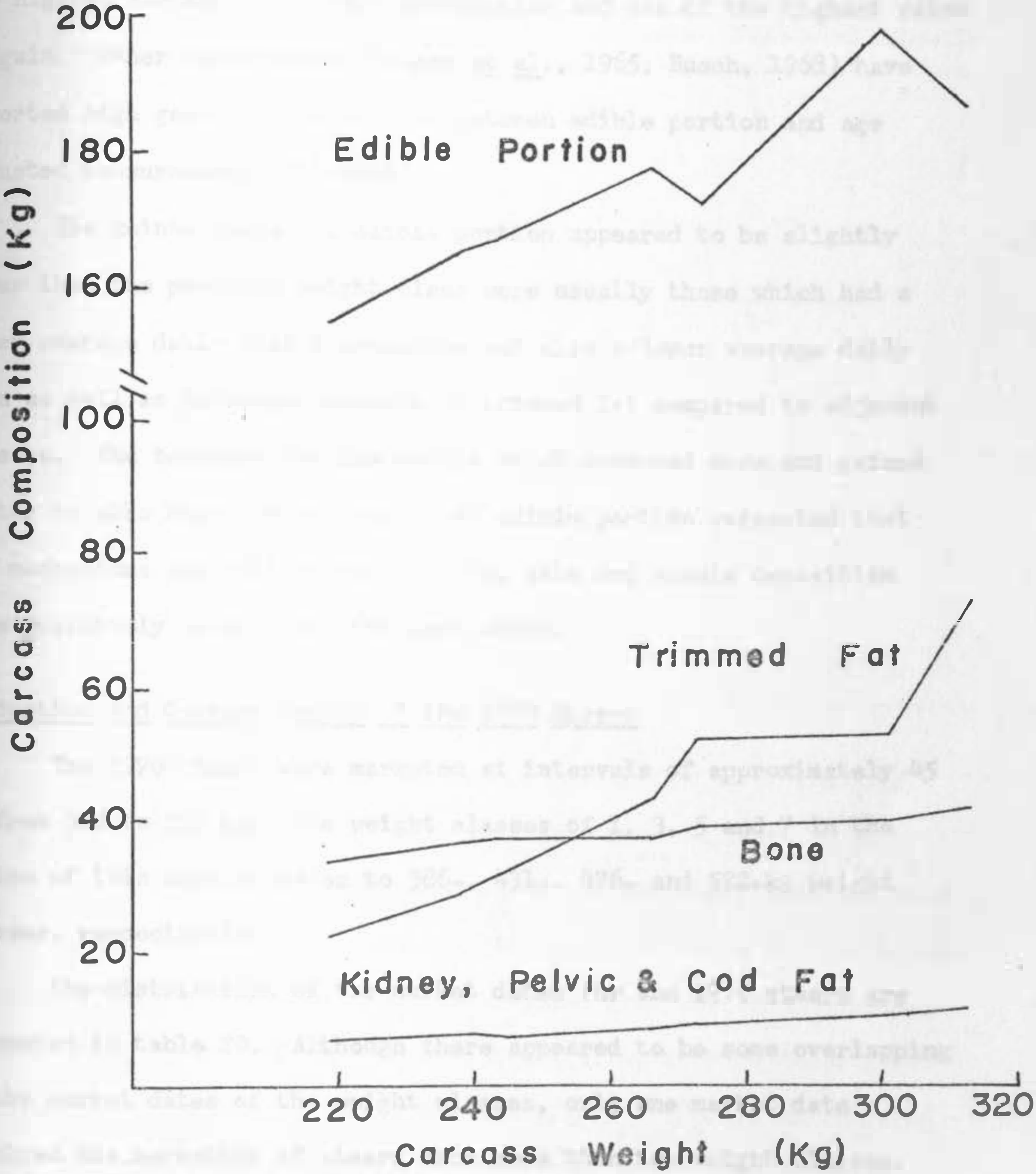

Figure 5. Relationship between carcass composition and carcass weight of the 1968 steers.

that group 6 which had the highest amount of edible portion also had the highest average daily feed consumption and one of the highest rates of gain. Other researchers (Swiger et al., 1965; Busch, 1968) have reported high genetic correlations between edible portion and age adjusted measurements of growth.

The points where the edible portion appeared to be slightly lower than the previous weight class were usually those which had a lower average daily feed consumption and also a lower average daily gain as well as increased amounts of trimmed fat compared to adjacent classes. The tendency for the groups which consumed more and gained faster to also have higher amounts of edible portion suggested that the mechanisms controlling consumption, gain and muscle deposition were positively associated with each other.

Production and Carcass Traits of the 1970 Steers

The 1970 steers were marketed at intervals of approximately 45 kg from 386 to 522 kg. The weight classes of 1, 3, 5 and 7 in the tables of this section refer to 386-, 431-, 476- and 522-kg weight classes, respectively.

The distribution of the market dates for the 1970 steers are presented in table 20. Although there appeared to be some overlapping in the market dates of the weight classes, only one market date involved the marketing of steers from more than two weight classes. There also appeared to be more uniformity within the weight class market dates than in the 1968 study.

TABLE 20. MARKET DATES OF 1970 WEIGHT CONSTANT STEERS

Date	Days on feed	Weight class 1	3	5	7
6-16-70	160	1			
6-29-70	174	1			
7-13-70	188	1	1		
7-27-70	202	1			
8-31-70	237	1	3		
9-14-70	251	1	1		
9-28-70	265		1	3	1
11-9-70	307			1	
12-7-70	335			1	1
12-21-70	349				2
Totals		6	6	5	4

The weight class means of the production traits of the 1970 steers are presented in table 21. No significant differences were observed for initial age, initial weight, average daily gain and feed per kg of live weight gain. The relatively small range in the initial weights as compared to the 1968 data allowed more useful comparisons of feed consumption between weight classes. The average daily gains were considerably lower for all classes of the 1970 data as compared to the 1968 data.

Significant differences were observed for days on feed, final weight, total feed consumption, average daily feed consumption and feed per kg of edible portion. The differences between days on feed,

TABLE 21. WEIGHT CLASS MEANS OF PRODUCTION TRAITS OF THE 1970 STEERS WITH F-TESTS OF SIGNIFICANCE

Trait	Weight class 1	3	5	7	F value
Initial age	272	269	266	274	0.7404
Days on feed	206	239	286	325	11.2838**
Initial wt, kg	225.3	222.2	231.5	240.8	1.6086
Final wt, kg	389.4	438.2	478.8	523.3	123.0800**
Total feed consumption, kg	1396.8	1789.6	2120.5	2657.0	23.1828**
Avg daily gain, kg	0.82	0.91	0.87	0.88	0.9887
Avg daily feed consumption, kg	6.81	7.48	7.40	8.20	8.9287*
Feed/kg live wt gain	8.40	8.31	8.55	9.40	1.8369
Feed/kg edible portion	9.14	10.79	12.11	14.30	8.6611*

* $P < .05$.
** $P < .01$.

final weight and total feed consumption were expected with the design of the weight constant experiment. Average daily feed consumption was lowest for animals marketed at weight class 1 and highest for those marketed at weight class 7. The higher feed consumption of group 7 had been expected as these steers were larger and also encountered colder environmental conditions prior to market. The lower average daily feed consumption of steers marketed in class 5 as compared to steers in class 3 was not expected. The amount of feed per kg of edible portion increased with each successive weight class. The increased amounts of feed for live weight gain and edible portion were expected as the animals were heavier. The feed per unit of edible portion was higher for all classes in the 1970 data than in the 1968 data. The slower rate of gain in the 1970 data was a contributing factor for the higher requirement. The feed required per unit of edible portion was considerably higher for the heavier weight classes as compared to the lower classes in both studies.

Examination of the intervals between the weight classes presented some interesting trends. The differences in days on feed were 33, 47 and 39 days between weight classes 1 to 3, 3 to 5 and 5 to 7. The live weight gains were 48.8, 40.6 and 44.5 kg, respectively, for the three intervals. These differences between intervals suggested that the rate of gain was lower for the interval between classes 3 and 5. The total feed consumption differences between the classes were 392.8, 330.9 and 536.5 kg. The lower feed consumption during the second interval was not expected. Although the small number of animals involved in this study increased the possibility of sampling error, the data of this study suggest that both the rate of gain and the average daily feed consumption were reduced during the interval between classes 3 and 5. The possibility exists that these changes were associated with the animals involved in comparisons of classes 3 and 5 or that the temperature computer measurements had affected the consumption patterns of animals in class 5. Examination of the individual feed consumption and weight gain data of all animals involved in classes 5 and 7 indicated that nearly all steers had considerable fluctuation in consumption and gain during the interval between weight classes 3 and 5. Nearly every steer appeared to go through a period of reduced performance during this interval. The normal practice of marketing cattle on the basis of average pen weight or length of time on feed probably averages over and hides the variation in performance which appeared to be present in this study. The determination of market time on the basis of individual weight allowed the examination of the effects of live weight which have been lost with other types of studies.

The weight class means of the carcass traits of the 1970 steers are presented in table 22. No significant differences between weight classes were observed for lean firmness, lean color, marbling, maturity, ribeye area, fat thickness, dressing percent, carcass grade, percent edible portion, percent fat trim and percent removed bone. The very small ranges as well as the small F values suggested that there was very little variation between weight classes for the commonly termed quality traits of the 1970 steers. A probable explanation for the fact that none of the carcass composition traits expressed as a percent of the carcass cutting weight were significantly different between weight classes was the relatively high amount of fat contained in the first two weight classes.

Significant differences were observed for kg of edible portion, trimmed fat, removed bone and the summation of the kidney, pelvic and cod fat. These differences were expected with the increasing intervals

TABLE 22. WEIGHT CLASS MEANS OF CARCASS TRAITS OF 1970 STEERS WITH F-TESTS OF SIGNIFICANCE

Trait	Weight class 1	3	5	7	F value
Lean firmness	4.9	5.2	5.5	5.8	0.8556
Lean color	5.5	4.7	4.5	4.5	0.9498
Marbling	4.6	4.7	4.6	4.5	0.0447
Maturity	23.3	23.1	22.9	23.0	0.4474
Ribeye area, cm^2	72.5	79.8	82.3	83.9	2.6977
Fat thickness, cm	1.15	1.18	1.46	1.77	3.4813
Dressing percent	60.7	60.4	61.6	60.6	0.5393
Carcass grade	18.4	17.7	18.1	18.0	0.2436
Edible portion, kg	153.5	167.5	174.8	185.9	6.3919*
Percent edible portion	68.0	66.7	63.5	62.8	2.7581
Fat, kg	40.6	49.3	61.7	71.0	11.2391**
Percent fat	18.0	19.8	22.3	23.9	2.6562
Bone, kg	31.4	33.8	39.0	39.4	14.1987**
Percent bone	13.9	13.4	14.2	13.3	1.2887
Kidney, pelvic and cod fat, kg	7.7	9.0	11.6	15.3	8.4046*

* $P < .05$.
** $P < .01$.

of approximately 45 kg live weight. However, the changes between each successive weight class were not the same as can be seen by examination of the relative growth patterns of edible portion, trimmed fat, removed bone and the summation of the kidney, pelvic and cod fat plotted against carcass weight in figure 6. The growth of the edible portion appeared to plateau between classes 3 and 5 and increased between classes 5 and 7 and supported the trends reported by Dinkel et al. (1969) and the 1968 data of this study.

The actual changes between intervals were 14.0, 7.3 and 11.1 kg. The actual values of edible portion were very nearly the same for corresponding classes of both the 1968 and 1970 data. The values were 154.9, 165.6, 173.9 and 187.4 kg for classes 1, 3, 5 and 7, respectively, of the 1968 data and 153.5, 167.5, 174.8 and 185.9 kg for the same classes in the 1970 data.

The interval changes of trimmed fat were 8.7, 12.4 and 9.3 kg for the three intervals and indicated that fat deposition increased during the same interval in which edible portion deposition was reduced. The 1970 steers had more trimmed fat at the lower weight classes than did the 1968 steers. The values of trimmed fat were 23.3, 29.6, 51.9 and 73.5 kg for classes 1, 3, 5 and 7 of the 1968 data and 40.6, 49.3, 61.7 and 71.0 kg for the four classes of the 1970 data. A possible explanation for the differences in the amount of trimmed fat between the two sets of data could have been related to the fact that the 1970 steers were started on the finishing ration in January, whereas the 1968 steers were not started on the ration until April.

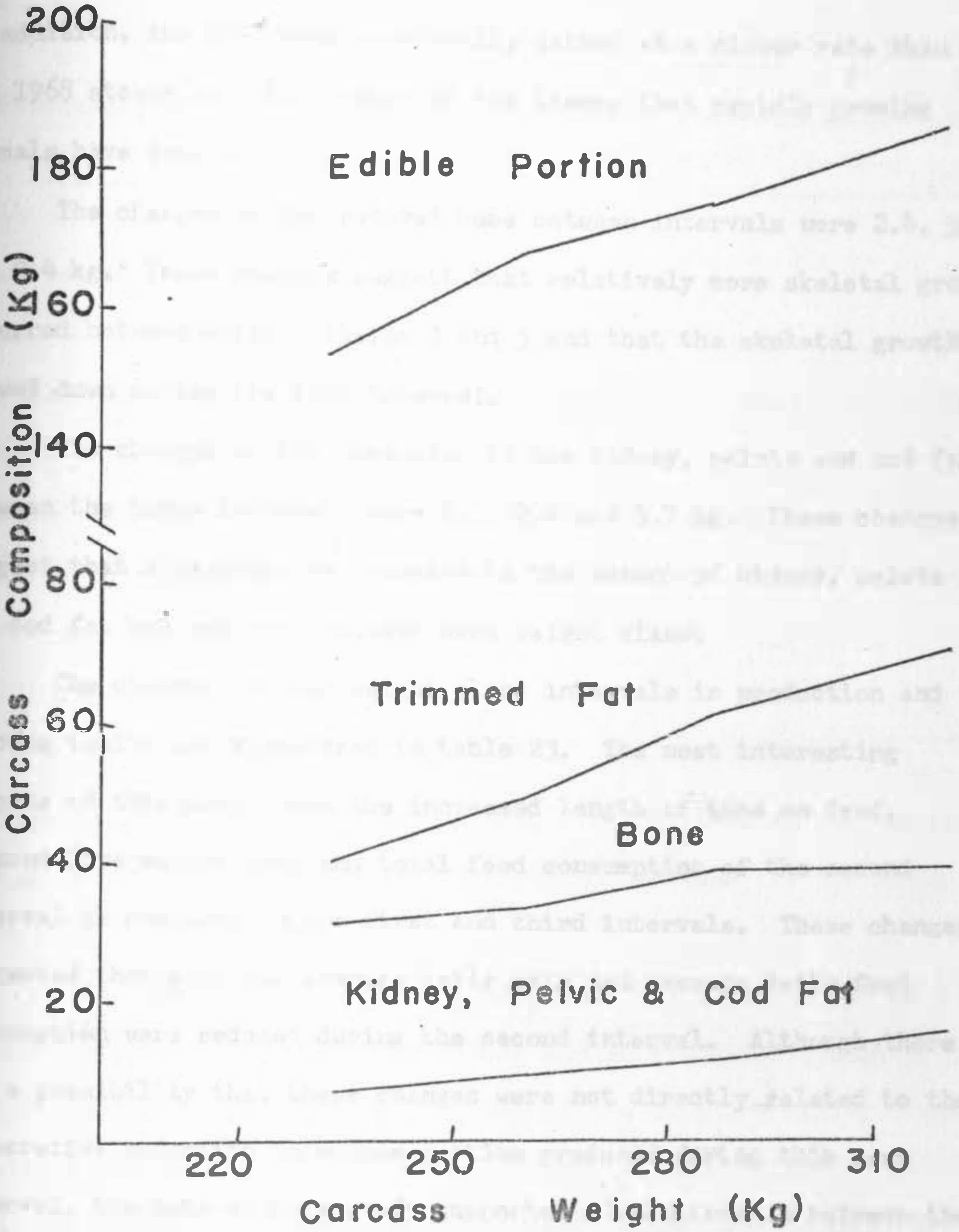

Figure 6. Relationship between carcass composition and carcass weight of the 1970 steers.

In addition, the 1970 steers generally gained at a slower rate than did the 1968 steers and thus supported the theory that rapidly growing animals have less fat.

The changes of the removed bone between intervals were 2.4, 5.2 and 0.4 kg. These changes suggest that relatively more skeletal growth occurred between weight classes 3 and 5 and that the skeletal growth slowed down during the last interval.

The changes in the summation of the kidney, pelvic and cod fat between the three intervals were 1.3, 2.6 and 3.7 kg. These changes suggest that a progressive increase in the amount of kidney, pelvic and cod fat had occurred between each weight class.

The changes between weight class intervals in production and carcass traits are summarized in table 23. The most interesting aspects of this table were the increased length of time on feed, reduced live weight gain and total feed consumption of the second interval as compared to the first and third intervals. These changes suggested that both the average daily gain and average daily feed consumption were reduced during the second interval. Although there was a possibility that these changes were not directly related to the comparative reduction in edible portion produced during this same interval, the data of this study supported a relationship between the lower feed intake, lower average daily gain and lower production of edible portion.

The ratios of feed per unit of edible portion gain were 28.1, 45.3 and 48.3 for the three intervals of the 1970 data. These ratios

TABLE 23. CHANGES OF PRODUCTION AND CARCASS COMPOSITION TRAITS OCCURRING BETWEEN WEIGHT CLASS INTERVALS

	Interval		
	1-3	3-5	5-7
Days on feed	33	47	39
Live weight gain, kg	48.8	40.6	44.5
Total feed consumption, kg	392.8	330.9	536.5
Carcass gain, kg	26.4	27.5	24.5
Edible portion, kg	14.0	7.3	11.1
Trimmed fat, kg	8.7	12.4	9.3
Removed bone, kg	2.4	5.2	0.4
Kidney, pelvic and cod fat, kg	1.3	2.6	3.7
Total carcass waste, kg	12.4	20.2	13.4

suggested that the costs of production of edible portion gain during the last two intervals were considerably higher than for the first interval.

The results of both studies supported the tendency for an edible portion plateau near the middle and an increased amount of edible portion deposition near the end of the curve. The 1970 steers gained slower and had more trimmed fat at the lower weights than did the 1968 steers. Feed efficiency expressed either on the basis of total edible portion or upon edible portion gain was lower for the heavier weight classes.

Economic Aspects of Production and Carcass Changes

Although certain trends in the production and carcass traits have been shown, costs and expected returns were necessary for a more complete evaluation of the profitability of marketing at the various weight classes. The comparative costs and expected returns of the 1968 steers are presented in table 24. The total feed costs and fixed costs increased as the number of days on feed increased. With the exception of the very sharp increase which occurred for animals of class 6, the feed costs per day increased at a relatively constant rate for each successive class. The total cost of production also increased with each successive weight class. For those readers who may be concerned about the effect of the variation in initial weight upon the cost comparisons, it should be indicated that total cost values obtained after adjustment to the same initial weight were very similar to those obtained using actual values. As has been indicated in the previous discussion of production traits, the fact that weight class 3 was on feed for fewer total days than classes 1 and 2 was probably associated both with sampling variation and a higher initial weight.

The carcass value represented the typical return to the producer when cattle were sold on the basis of total carcass weight under the current price structure. The price of one dollar per kg was chosen because it was representative of actual dressed beef prices and also because total carcass value was equal to carcass weight. Under this price structure, the highest carcass value was for weight class 7.

TABLE 24. COMPARATIVE COSTS AND RETURNS OF THE 1968 STEERS[a]

Item	Weight class						
	1	2	3	4	5	6	7
Number of steers	4	5	4	3	5	4	4
Initial cost ($.6174/kg)	156.14	170.59	190.22	182.57	176.14	187.63	175.96
Total feed cost ($.05/kg)	38.62	48.39	33.34	47.85	62.30	69.03	81.17
Feed cost per day	0.36	0.37	0.38	0.39	0.40	0.46	0.41
Total fixed costs ($.10/day)	10.60	13.20	8.70	12.20	15.70	15.00	19.60
Total production cost	205.36	232.18	232.26	242.62	254.14	271.66	276.73
Carcass value ($1.00/kg)	219.00	242.50	239.40	266.60	273.80	300.70	312.80
Total net return	13.64	10.32	7.14	23.98	18.66	29.04	36.07
Net return per day	0.13	0.08	0.08	0.20	0.12	0.19	0.18
Necessary selling price of edible portion per kg	1.41	1.45	1.45	1.50	1.57	1.51	1.67
PROFIT WHEN PRODUCT WAS PURCHASED ON THE BASIS OF EDIBLE PORTION (E.P.)							
Profit (E.P. = $1.50/kg)	27.00	18.20	16.10	24.70	6.70	26.20	4.40
Profit per day	0.25	0.13	0.19	0.22	0.04	0.17	0.02
Profit (E.P. = $1.75/kg)	65.70	59.90	57.50	69.20	50.20	75.90	51.20
Profit per day	0.61	0.45	0.66	0.57	0.32	0.51	0.26

[a] All values in the table are in terms of dollars per head. The production and carcass values used in the calculations were presented in tables 18 and 19.

The total net return to the producer was also highest for class 7. However, the number of days on feed was also longest for this class. Classes 4, 6 and 7 were similar when net return was calculated on a per day basis. Similar total net returns per year could be obtained by marketing more cattle at lighter weights. The data of this study indicated that approximately 1.6 times as many steers could be finished to weight class 4 as could be finished to weight class 7. The total net returns would be similar as the values were $38.38 and $36.07 for 1.6 groups of class 4 and 1.0 group of class 7, respectively.

As the edible portion represented the amount of salable meat under the current consumer demands, the fat and bone were waste products of essentially no economic value. Therefore, the necessary selling price represented the price at which the edible portion had to be sold to recover the cost of the animal purchased on a total carcass basis. Examination of the necessary selling price suggested that under our current system the edible portion was not of the same value for all classes. The fact that the cattle of this study did not differ significantly in carcass grade suggested that the differential prices for edible portion were not justified.

Therefore, the expected profits on the basis of selling only edible portion were calculated. Expected profits were calculated with a low and a premium price for the edible product. The basic assumption necessary for the same price per unit of edible portion was that the quality and consumer acceptance of the edible portion did not change between weight classes. When the steers were priced on the basis of edible portion, the highest profits were achieved for classes 1, 4 and 6. The profit or net return for class 7 under this price structure was considerably lower than when the value was determined by carcass weight alone. The price system based upon edible portion rewarded the producer of the desirable product and discounted the production of excessive waste.

The variations of profits for the last three weight classes were similar to the fluctuations observed in the edible portion production curve. Until more data are collected to verify the rapid rise in edible portion which occurred in class 6 of this study, a producer selling on the basis of edible portion should consider marketing at weight class 4 or at a weight of approximately 454 kg. Weight class 4 was one of the highest profit groups under any of the pricing systems. The net return per day was highest for class 4 under the conventional system. The animals of class 4 produced a carcass with a high lean to fat ratio of acceptable grade. A producer could feed and market three times a year when the cattle were marketed at class 4. In addition, the product produced could be used by the industry without the excessive trimming of fat.

The relative relationship between the two price levels for edible portion and the cost of production of edible portion are shown in figure 7. The price lines were determined by plotting total return vs. kg of edible portion. The regression line of costs of production upon edible portion produced was computed with the data of 29 individual steers in the 1968 study. The total profit can be

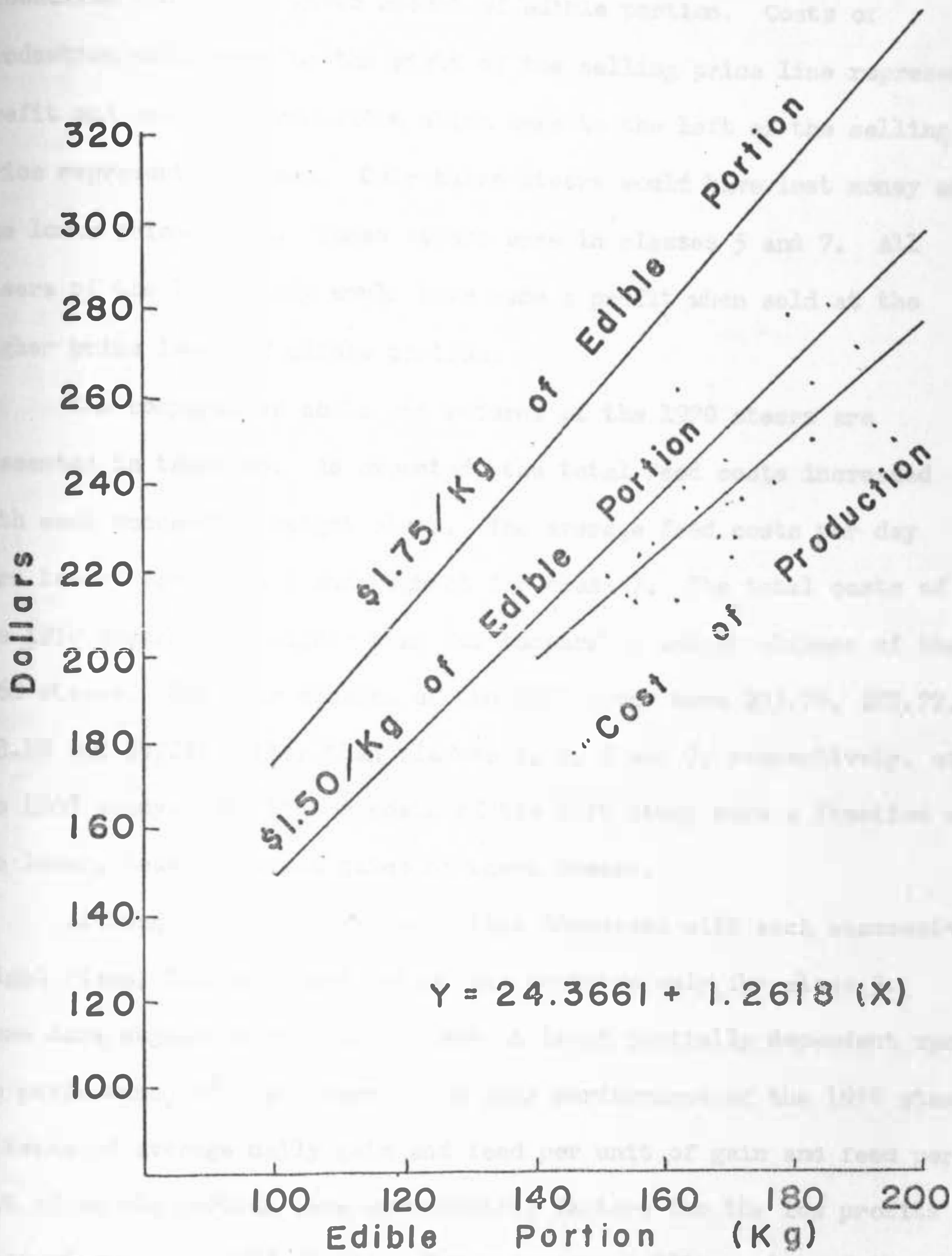

Figure 7. Relationship between price levels, cost of production and edible portion of the 1968 steers.

determined by measuring the distance between the price and costs of production line for a given amount of edible portion. Costs of production which were to the right of the selling price line represented profit and costs of production which were to the left of the selling price represented losses. Only three steers would have lost money at the lower price level. These steers were in classes 5 and 7. All steers of the 1968 study would have made a profit when sold at the higher price level of edible portion.

The comparative costs and returns of the 1970 steers are presented in table 25. As expected, the total feed costs increased with each successive weight class. The average feed costs per day were lowest for class 1 and highest for class 7. The total costs of the 1970 steers were higher than for comparable weight classes of the 1968 steers. The four classes of the 1970 study were \$33.78, \$27.77, \$33.28 and \$47.52 higher than classes 1, 3, 5 and 7, respectively, of the 1968 study. The higher costs of the 1970 study were a function of the lower, less efficient gains of these steers.

Although the total carcass value increased with each successive weight class, the total net return was positive only for class 3. These data suggested that profit was at least partially dependent upon the performance of the steers. The poor performance of the 1970 steers in terms of average daily gain and feed per unit of gain and feed per unit of edible portion were contributing factors for the low profits obtained with the 1970 steers. The necessary selling price of the edible portion indicated that, in agreement with the 1968 study, the

TABLE 25. COMPARATIVE COSTS AND RETURNS OF THE 1970 STEERS[a]

Item	Weight class 1	3	5	7
Number of steers	6	6	5	4
Initial cost ($.6615/kg)	148.70	146.65	152.79	158.90
Total feed cost ($.05/kg)	69.84	89.48	106.03	132.85
Feed cost per day	0.34	0.37	0.37	0.41
Total fixed costs ($.10/kg)	20.60	23.90	28.60	32.50
Total production cost	239.14	260.03	287.42	324.25
Carcass value ($1.00/kg)	233.20	259.60	287.10	311.60
Total net return	-5.94	1.43	-.32	-12.65
Net return per day	-.029	0.006	-.001	-.039
Necessary selling price of edible portion per kg	1.52	1.55	1.64	1.68
PROFIT WHEN PRODUCT WAS PURCHASED ON THE BASIS OF EDIBLE PORTION ONLY				
Profit (E.P. = $1.50/kg)	-8.90	-8.75	-25.20	-45.40
Profit per day	-.043	-.037	-.088	-.140
Profit (E.P. = $1.75/kg)	29.50	33.10	18.50	1.08
Profit per day	0.14	0.14	0.06	0.003

[a] All values in the table are in terms of dollars per head. The production and carcass values used in calculations were presented in tables 21 and 22.

value per unit of edible portion was not the same for all weight classes. The necessary selling price per kg of edible portion was higher for the heavier classes than for the lower classes. The profits when the steers were sold on the basis of edible portion were negative for all classes at the lower level and positive for all classes at the higher level of edible portion. The comparative profits were highest for class 3 under all pricing systems.

The economic comparisons of both the 1968 and 1970 data indicated that the per day return was near maximum prior to the plateau area which occurred during weight class 5 of both studies. The relatively higher returns obtained with the 1968 steers were probably the result of the faster, more efficient gains of this group of steers. The data of both studies also indicate that under the current pricing system the value per unit of edible portion was not the same. At the present time a pricing system based upon edible portion would encourage the production of a high lean to fat ratio product which would be more economical for the total industry. In addition, a pricing system based upon edible portion would provide incentive for production of a more desirable product as well as a more profitable industry.

Comparative Energy Utilization Between Weight Classes

The third objective of this study was concerned with the utilization of the temperature computer measurements and production data to partition the theoretical energy utilization during the intervals between weight classes. This partition will be useful in attempting to better understand changes in production and carcass composition which were presented in the previous section.

The temperature computer measurements used in this section were not adjusted for differences in ambient temperature. The unadjusted temperature computer measurements were representative of the environmental temperature differences in which the steers were raised and also the temperature conditions in which feed consumption and other production traits were measured. The weight class means of temperature computer measurements which were used to compute heat loss are presented in table 26. Each value in the table represented the mean of all steers in each weight class measured in the first and last measurement period of the day. Although ambient temperatures were very similar for weight classes 1 and 3, the ambient temperature decreased for weight classes 5 and 7, as expected with the range of measurements taken from June until December. The mean skin temperatures were also similar for the first two weight classes and were lower for each of the two heavier classes. The difference between the mean skin and ambient temperatures or the theoretical amount of temperature difference which was available as the potential lost to the environment was nearly the same for weight classes 1 and 3 and increased for classes 5 and 7. The amount of heat which was expected to be lost to the environment per square meter of surface area per hour was also nearly the same for classes 1 and 3 and increased for both classes 5 and 7.

The temperature measurements taken in this study were useful for the comparison of the effects of varying ambient temperature upon animals in still environmental temperatures. However, other environmental effects such as wind, humidity and solar radiation were not considered. Therefore, the effects measured in this study must be considered as pertaining only to still air temperatures under shade and varying humidity levels.

The mean of each of the traits which were used in the calculation of the daily energy partition during the intervals between weight classes are presented in table 27. With the exception of daily gain

TABLE 26. WEIGHT CLASS MEANS OF UNADJUSTED TEMPERATURE COMPUTER MEASUREMENTS

Measurement	Weight class 1	3	5	7
Ambient, C	20.15	20.55	13.26	9.25
$\bar{x}$ skin, C	34.33	34.55	32.45	30.65
($\bar{x}$ skin - ambient), C	14.18	14.00	19.19	21.40
Heat loss, kcal/hr/m^2	77.99	77.00	105.54	117.70

TABLE 27. COMPARISON OF MEAN VALUES BETWEEN WEIGHT CLASS INTERVALS

Item	Interval 1-3	3-5	5-7
Days in interval	33	47	39
Mean live weight, kg[a]	413.8	458.5	501.1
Mean metabolic size, $wt_{kg}^{3/4}$[b]	91.8	99.0	105.9
Mean surface area, m^2[c]	4.6	4.9	5.2
Mean daily gain, kg[d]	1.48	0.86	1.14
Mean daily feed consumed, kg[e]	11.90	7.04	13.76
Mean skin - ambient, C[f]	14.1	16.6	20.3

[a] The mean live weight was equal to the summation of each successive weight class divided by two.

[b] The mean metabolic size was equal to the mean live weight raised to the 3/4 power.

[c] The mean surface area was equal to the mean live weight raised to the .6 power as given by the formula of Brody (1928).

[d] The mean daily gain was equal to the difference of successive weight classes divided by the days in the interval between successive weight classes.

[e] The mean daily feed consumption was equal to the difference between successive weight classes divided by the days in the interval between successive classes.

[f] The mean skin - ambient was equal to the summation of each successive weight class value of (mean skin - ambient) divided by two.

and feed consumption, all traits increased with successive intervals as was expected with increasing body weight and decreasing environmental temperatures.

The mean daily energy utilization for the intervals between the weight classes are presented in table 28. The average calculated metabolizable energy intake per day was markedly lower for the interval between weight classes 3 and 5. The metabolizable energy intake for this interval was also lower than that suggested by the National Research Council (1970). The fact that the metabolizable energy intake was lower than required suggested that there may have been a period of time during this interval when the steers were in a negative energy balance. Variations in feed consumption occurred and there were tendencies in the data which suggested that all steers went through a period of lower feed consumption during the interval between the classes 3 and 5. The lower feed consumption during the second interval and the lower environmental temperature may have stimulated the higher feed consumption during the interval between classes 5 and 7. The fact that the animals were slaughtered on a weight constant basis required the animal to make a positive gain during the period. However, the extended length of time and reduced mean daily gain and mean daily feed consumption favored the theory that there was a period of less than optimum performance during this interval.

The temperature computer heat loss increased with each successive interval as had been expected with increased body size and also

TABLE 28. COMPARISON OF MEAN DAILY ENERGY PARTITION FOR THE INTERVALS BETWEEN WEIGHT CLASSES

Trait	Interval		
	1-3	3-5	5-7
Metabolizable energy (M.E.), Mcal[a]	30.8	18.2	35.5
Temperature computer heat loss (T.C.), Mcal[b]	8.6	10.7	13.9
Basal metabolism (B.M.), Mcal[c]	6.4	6.9	7.4
T.C. - B.M., Mcal[d]	2.2	3.8	6.5
M.E. - T.C., Mcal[e]	22.2	7.5	21.6
Gain, Mcal[f]	8.5	5.0	7.3
Unaccounted, Mcal[g]	13.7	2.5	14.3

[a] Metabolizable energy was calculated as 2583.6 kcal per kg feed intake from values given by Crampton and Harris (1969).

[b] Temperature computer heat loss is equal to heat loss per hour multiplied by 24.

[c] Basal metabolism is equal to $70 \times W_{kg}^{0.75}$.

[d] T.C. - B.M. represents the additional energy above basal for standing and the environmental temperature heat loss.

[e] M.E. - T.C. is the difference between the metabolizable energy intake and the heat loss to the environment.

[f] Energy in gain was calculated as $(52.72g + 6.84g^2)(W_{kg}^{0.75})$ as given by Lofgreen and Garrett (1968).

[g] Unaccounted is the remainder from M.E. - T.C. + energy in gain.

decreased environmental temperatures with each successive interval. Calculated basal metabolism values increased with each interval. The difference between temperature computer and basal metabolism heat losses increased with successive intervals as was expected with the increased body weight and decreased environmental temperature.

The difference between metabolizable energy and temperature computer heat loss, or that energy which was theoretically available for production after losses to the environment and normal body metabolism were considered, was considerably lower for the second interval. The similar amount of available energy for both the first and third intervals suggested that the colder environmental temperatures during the third interval may have been a factor responsible for the increase of approximately 4.7 Mcal of metabolizable energy intake from the first to the third interval. Other workers (Kleiber, 1961; Winchester, 1964) have indicated that consumption increased in colder environmental temperatures. The ability of the temperature computer to measure both temperature of the animal and the ambient and the measurement of feed consumption was a useful method of comparing effects of temperature upon feed consumption. However, these measurements did not take into account the effects of wind, humidity and solar radiation.

The energy content of the gains indicated that the first interval gains were highest and that the lowest amount of energy was deposited during the second interval. Although the available energy was only slightly lower for interval three as compared to interval one, a smaller amount of energy was accounted for by gain. The lower efficiency of gain was expected due to the larger body size maintained during the last interval. The amount of unaccounted for energy followed the same pattern as the metabolizable energy with the lowest value for the middle interval and nearly the same amounts for the first and third intervals.

Although the small number of animals involved in this study increased the probability of large sampling errors, there appeared to be a relationship between the lower energy intake and the lower amount of edible portion produced during the interval between classes 3 and 5. Although quite speculative, the mobilization of body muscle protein during a part of this period of lower energy intake might have been responsible for the reduction or plateau in edible portion production. According to Berg and Butterfield (1968), a low plane of nutrition tended to retard the development of fat and muscle and semi-starvation depletes fat and muscle with some depletion of bone. In addition, the realimentation leads to compensation whereby muscle and bone relationships were restored and fat tissue proportion increased in relation to the plane of nutrition and the length of the compensation period. Although all steers were allowed *ad libitum* feed consumption, considerable variation in consumption patterns occurred. The data of this study suggested that the feed consumption or energy intake during the interval between class 3 and 5 was not adequate for the maximum growth of edible portion. The fact that consumption was higher during the last interval and also that edible portion increased would tend to support this speculation.

Preston (1971) has indicated that the carcasses of lambs which had been fed to weights of approximately 59 kg and then fed a reducing diet until the lambs weighed approximately 45 kg contained more fat than did lambs fed continuously to 45 kg. These lambs which were reduced from 59 to 45 kg did not lose proportionately greater amounts of fat and, therefore, when evaluated at 45 kg contained significantly greater amounts of fat than lambs continuously grown to this weight.

The author suggested that ruminants in negative energy balance catabolized large amounts of protein to yield glucogenic amino acids for metabolism. He also suggested that severe weight loss over a period of time could result in a disproportionate loss of protein from which the animal could not recover and therefore resulted in carcasses which contained greater proportions of fat.

Similar alterations in protein metabolism and deposition may have occurred during the interval between classes 3 and 5 of this study. Examination of the individual shrunk weights suggested that nearly every steer had a period of either negative, zero or only a small positive gain between classes 3 and 5. The lower than recommended energy intake over the period suggested the possibility of a short period of negative energy balance. The occurrence of lower energy consumption and also a lower amount of edible portion production during this interval suggested that changes similar to those observed in reducing or semi-starvation studies had occurred.

The changes in feed consumption and edible portion during the interval between classes 5 and 7 may have been caused by endocrine or physiological alterations in protein and fat synthesis and deposition mechanisms. Cyclic fluctuations of hormone levels such as growth hormone may be associated with these occurrences. Future studies should evaluate feed consumption patterns with respect to changes in weight and carcass composition on large numbers of animals. The measurement of growth hormone and other hormones at periodic intervals may be important areas for future research.

SUMMARY AND CONCLUSIONS

This study has examined the usefulness and relationships between temperature computer measurements, production traits, carcass traits and the edible portion growth curve of individually fed weight constant steers raised in a near normal or conventional manner.

The first temperature computer experiment utilized steers which had been designated as substitutes at allotment time. This experiment was conducted to evaluate ambient temperature effects as well as measurement periods within the same day, measurement time during the summer and sire group differences. Ambient temperature significantly affected all surface temperatures but did not significantly affect the rectal temperature in the ambient temperature range of approximately 15 to 24 C. After adjustment for significant ambient temperature effects, no surface temperatures were significantly different for measurement periods within the same day. The rectal temperatures of the animals measured during the normal feeding time and in the first period after feeding were significantly higher than in other periods. Examination of measurement time during the summer suggested that significant differences in mean skin temperature occurred during growth, with a tendency for the mean skin temperature to decrease. The significant sire difference obtained in this experiment could have been due in part to the variability in weight and other characteristics of the substitute steers. In addition, day of measurement and sire group were confounded.

The second temperature computer experiment evaluated the measurements taken in two periods prior to slaughter of the weight constant steers. The ambient temperature ranged from approximately 4 to 24 C. Ambient temperature significantly affected all temperature computer measurements. After adjustment for ambient temperature, no important differences were observed for weight class, period or breed of sire.

The second specific objective was concerned with the evaluation of sources of variation in the production and carcass traits of two groups of individually fed steers.

The 1968 trial included 29 Hereford steers which were individually fed and marketed at seven constant weights from approximately 386 to 522 kg in intervals of approximately 22.7 kg. In general the carcass composition growth followed the trends of earlier work reported by Dinkel et al. (1969). These trends were characterized by a plateau near the middle and a marked increase in edible portion near 500 kg. Lower feed consumption and slower gains appeared to be associated with the plateau or reduction of edible portion. The ratio of feed per unit of edible portion increased with increasing number of days on feed and was also higher for the three heaviest weight classes. Even though the total edible portion increased after the plateau, the efficiency of production of total edible portion and the net return per day indicated that the steers should have been marketed prior to the plateau or at a weight of approximately 454 kg shrunk live weight.

The 21 Angus and Hereford sired crossbred steers which successfully completed the 1970 trial were marketed at four constant weights from approximately 386 to 522 kg in intervals of approximately 45 kg. The edible portion growth of the steers in this trial tended to follow the trends of earlier work with the plateau near the middle and an increased amount of edible portion after the plateau. The results of this trial suggested a reduction of feed consumption, production of less edible portion and more fat and bone during the middle interval as compared to the other intervals. The ratio of feed per kg of edible portion increased with each successive weight class. The amount of feed per each kg gained between weight class intervals was considerably higher for the heavier intervals. Therefore, the efficiency of production of edible portion and also the net return per day suggested that the steers should have been marketed prior to the plateau between classes 3 and 5.

The third objective involved the utilization of the unadjusted temperature computer measurements and production data for calculation of the theoretical partition of energy utilization between weight class intervals of the 1970 trial. The calculated metabolizable energy intake was considerably less for the middle interval and was also lower than recommended by the National Research Council (1970). This suggested that there may have been a period of inadequate energy intake during the interval the plateau in edible portion occurred.

Studies of animals which have been forced to undergo negative energy balance have suggested that these animals catabolized body tissue proteins and thus altered the body composition. There was a possibility that a similar type of mechanism was functioning during the plateau period of the edible portion growth curve.

The increased amounts of temperature computer heat loss during the last interval suggested that the colder environment was at least partially responsible for the increased metabolizable energy intake during the last interval. The energy available for production, after losses for normal body function and heat loss to the environment were considered, was nearly the same for intervals one and three but was considerably lower for the second interval. Although the available energy was nearly the same for the first and third intervals, the efficiency of both live weight gain and edible portion gain was higher for the first interval.

More experiments should be conducted to evaluate the effects of feed consumption patterns upon the carcass composition. Future studies should involve the measurement of growth hormone level at periodic intervals and examination of the relationship of hormone level with respect to changes in the apparent plateau area.

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